Neotropical Ichthyology

Original article

https://doi.org/10.1590/1982-0224-2025-0034

Research goals of special concern for *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae) in Latin America – biological, distributional, and conservation priorities

Correspondence:
Peter Gausmann
peter.gausmann@rub.de

Peter Gausmann[1,2], Philip Matich[3,4] and Nadia Sandoval Laurrabaquio-Alvarado[5,6]

The bull shark (*Carcharhinus leucas*) is a coastal predator that relies on low salinity habitats (estuaries, rivers, lakes) for reproduction. Identifying inshore nurseries and parturition areas is critical to its conservation. Resulting from both coastal development and overfishing across its range, these habitats have increasingly experienced human impacts, resulting in declining populations. *Carcharhinus leucas* also shows data deficiencies across much of its range, including Latin America. In this region, several freshwaters historically reported as nurseries have been overfished and are now understudied. In this context, our study aims to identify and highlight research deficits for *C. leucas* in Latin America. To achieve this goal, we sought the expertise of 110 scientists from Latin America (34% response rate) and conducted a literature review to identify the most urgent research questions pertaining to *C. leucas*. The interviewed scientists highlighted many different research needs, with fisheries impacts, habitat use, and distribution being the most important. We identified seven sites of special importance for the conservation of *C. leucas* in Latin America, with four of these confirmed by Latin American scientists. This study not only outlines scientific research goals for *C. leucas* but provides investigation methods to gather essential data to address data deficiencies.

Keywords: Chondrichthyes, Conservation, Data-poor regions, Euryhaline species, Freshwater elasmobranchs.

Submitted July 26, 2024
Accepted May 27, 2025
Epub November 7, 2025

Associate Editor Jennifer Wyffels
Section Editor Toby Daly-Engel
Editor-in-chief Carla Pavanelli

1 Geographisches Institut, Fakultät für Geowissenschaften, Ruhr-Universität Bochum, Universitätsstr. 150, 44801 Bochum, North Rhine-Westphalia, Germany. peter.gausmann@rub.de (corresponding author).

2 Deutsche Elasmobranchier-Gesellschaft e.V., Centrum für Naturkunde, Universität Hamburg, Martin-Luther-King-Platz 3, 20146 Hamburg, Germany.

3 Saving the Blue, Cooper City, Florida 33328, USA. matich.philip@gmail.com.

4 Marine Biology Department, College of Marine Sciences & Maritime Studies, Texas A & M University at Galveston, Galveston, Texas 77554, USA.

5 El Colegio de la Frontera Sur, Av. Rancho Polígono 2-A, Ciudad Industrial, CP 24500 Lerma, Campeche, Mexico. nadia.sandoval@guest.ecosur.mx.

6 Takata Research Center A. C. Mahahual s/n, CP 77976, Municipio Othón P. Blanco, Quintana Roo, Mexico.

Online version ISSN 1982-0224
Print version ISSN 1679-6225

Neotrop. Ichthyol.
vol. 23, no. 3, Maringá 2025

O tubarão-cabeça-chata (*Carcharhinus leucas*) é um predador costeiro que depende de habitats com baixa salinidade (estuários, rios, lagos) para se reproduzir. Identificar os berçários costeiros e as áreas de parto é fundamental para sua conservação. Como resultado do desenvolvimento costeiro e da pesca excessiva em toda a sua área de distribuição, esses habitats têm sofrido cada vez mais impactos humanos, resultando no declínio das populações. *Carcharhinus leucas* também apresenta deficiências de dados em grande parte de sua área de distribuição, incluindo a América Latina. Nessa região, várias águas doces historicamente relatadas como berçários foram sobrepescadas e agora são pouco estudadas. Nesse contexto, nosso estudo visa identificar e destacar as lacunas de pesquisa sobre o *C. leucas* na América Latina. Para atingir esse objetivo, buscamos a expertise de 110 cientistas da América Latina (taxa de resposta de 34%) e realizamos uma revisão da literatura para identificar as questões de pesquisa mais urgentes relacionadas ao *C. leucas*. Os cientistas entrevistados destacaram muitas necessidades de pesquisa diferentes, sendo as mais importantes os impactos da pesca, o uso do habitat e a distribuição. Identificamos sete locais de especial importância para a conservação do *C. leucas* na América Latina, sendo quatro deles confirmados por cientistas latino-americanos. Este estudo não apenas delineia os objetivos da pesquisa científica para o *C. leucas*, mas também fornece métodos de investigação para coletar dados essenciais para lidar com as deficiências de dados.

Palavras-chave: Chondrichthyes, Conservação, Elasmobrânquios de água doce, Espécies eurialinas, Regiões com poucos dados.

INTRODUCTION

As the human population and its footprint continue to grow, so too does our need to identify and pursue ever-changing conservation goals. Habitat degradation, wildlife declines, and the loss of biodiversity are among the top priorities (Turner *et al*., 2024). In the ocean, overfishing is also a significant concern, particularly for sharks and rays with over one-third of extant species threatened by extinction (Dulvy *et al*., 2021; Pacoureau *et al*., 2023; Torres-Romero, Pérez Jiménez, 2024). More than 100 million sharks are killed each year (Worm *et al*., 2024), and persistent overharvesting of many species of chondrichthyans has led to severe population declines and conservation crises. Globally, sharks and rays have faced declines of more than half of their populations since 1970 (Dulvy *et al*., 2024), which is of concern for conservation as well as food and economic security. Due to these serious population declines, chondrichthyans (sharks, skates, rays, and chimaeras) belong to the most threatened vertebrate lineages (Temple *et al*., 2025).

Among sharks, the speciose family Carcharhinidae Jordan & Evermann, 1896 (requiem sharks) is the most economically important family for fisheries in the tropics, because of its core distribution in lower latitudes (Compagno, 1984). Rosales-Melgar *et al*. (2024) reported that between 2014–2022, exports from Central America almost exclusively consisted of Carcharhinidae species (96.4%). Globally, requiem sharks were recently estimated to comprise one-third of the annual chondrichthyan catch and two-thirds of the

fin trade of coastal sharks, and because they are inadequately managed in many regions, 71% of Carcharhinidae species are threatened worldwide (Sherman *et al*., 2023). Thus, there is an urgent need for conservation measures for these sharks. The recent addition of Carcharhinidae to CITES Appendix II (United Nations, 2024) was an important international step toward addressing this need. However, clarity on management and conservation priorities are still lacking in many regions, which will require stock assessments and more thorough monitoring of fisheries landings and bycatch.

Among the cosmopolitan species of requiem sharks that require additional conservation attention, *Carcharhinus leucas* (Valenciennes, 1839), the bull shark, has one of the highest encounter rates with humans, because of its proclivity to use coastal, estuarine, and connected freshwater habitats in the tropical, subtropical, and warm-temperate regions of the world (Compagno, 1984; Ebert *et al*., 2021). This euryhaline shark connects freshwater and marine food webs (Rosenblatt *et al*., 2013; Matich *et al*., 2020a,b, 2021), and is exposed to numerous threats across its distribution, including overfishing and habitat loss, with severe population declines reported for many regions (*e.g*., Asiedu *et al*., 2024). As such, *C. leucas* is assessed by the International Union for the Conservation of Nature (IUCN) as Vulnerable (VU) and globally decreasing (Rigby *et al*., 2021).

In addition to overfishing and habitat loss, *C. leucas* populations also suffer from mitigation measures targeting the reduction of shark bites such as culling, drumlines, and shark nets that are primarily used in countries with high numbers of tourist water users such as Brazil, South Africa, and Australia (Haig *et al*., 2018; O'Connell *et al*., 2022). These measures represent lethal strategies and have the potential to significantly reduce local stocks (Roff *et al*., 2018; Mourier *et al*., 2021), particularly because *C. leucas* has a very low recovery potential attributed to its late-maturation and low reproductive output (Cailliet *et al*., 2005; Saldaña-Ruiz *et al*., 2022). The age of maturation has been estimated from 9–18 years for *C. leucas* (Branstetter, Stiles, 1987; Cruz-Martínez *et al*., 2005; Neer *et al*., 2005; Natanson *et al*., 2014), and the maximum reported litter size is 14 pups in the Indian Ocean (Nevill *et al*., 2013). Considering these conservative life history traits with its purported biennial reproductive cycle (Jara-Aguirre, 2021), *C. leucas* has a very limited intrinsic rebound potential of r = 0.027 (comparable to the near-related *C. plumbeus* (r = 0.028); Smith *et al*., 1998), hindering the species' capacity to withstand population depletion. Thus, this shark is highly susceptible to overexploitation, which makes it a conservation priority.

Research on *C. leucas* has provided important knowledge and insight into the behavior, biology, and ecology of this species (*e.g*., Curtis *et al*., 2011, 2013; Heupel, Simpfendorfer, 2011; Tillett *et al*., 2012; Daly *et al*., 2014; Lea *et al*., 2015; Matich, Heithaus, 2015; Constance *et al*., 2024; Gausmann, 2024). However, well-investigated areas are mainly in the developed world (*e.g*., Australia, South Africa, United States), with large parts of the bull shark's range considered data-poor, including Latin America (a definition of this area is given in the Material and Methods section), which is a major provider of shark fins to the Asian shark fin market (Shea, Slee, 2024). In Latin America, many shark fisheries are unregulated, unenforced, and/or unreported/underreported (Zarate, Hearn, 2008; López-Garro, Zanella, 2021), and although *C. leucas* is reported to be rarely a target species, it is commonly caught in both commercial and recreational fisheries (Simpfendorfer, Burgess, 2005). Applegate *et al*. (1993) reported that *C. leucas* was probably the most important commercially fished shark species in the Caribbean

waters of Mexico, which was recently confirmed by Diario Oficial de la Federación (2022). However, *C. leucas* has declined over the last three decades as a result of overfishing in Campeche (Fig. 1), Quintana Roo, Tamaulipas, Veracruz, and Yucatan (Bonfil, 1994, 1997; Marcos-Camacho *et al*., 2016; Álvarez *et al*., 2020; Martínez-Candelas *et al*., 2020). Similarly, landings of *C. leucas* have noticeably decreased in the Gulf of California since 1939 (Saldaña-Ruiz *et al*., 2017). *Carcharhinus leucas* is also an important target species in other parts of Latin America, including the mouth of the Amazon River (Marajoara Gulf) (Alencar *et al*., 2001; Barthem, 2015), the neighbouring Maranhão, Brazil (Piorski *et al*., 2021), and coastal Ecuador (Martínez-Ortíz *et al*., 2007; Souza-Araujo *et al*., 2021), highlighting the exploitation of *C. leucas* across this region.

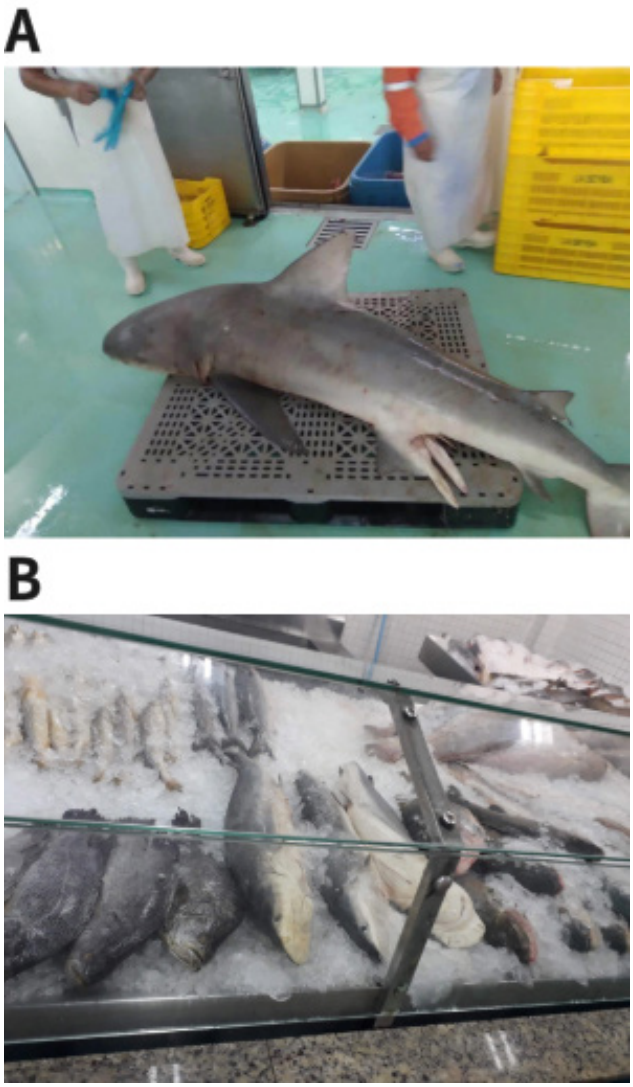

FIGURE 1 | A. Bull sharks such as this single specimen landed on the 23rd August 2023 at Seybaplaya, Campeche, Mexico, are targeted in great numbers by artisanal, small-scale, and industrial fisheries in the waters of the southern Gulf of Mexico (© Andrés Irigoyen-Solis). **B.** Small juvenile bull sharks displayed to be sold at the "Ver-o-Peso" fish market in Belém, Pará, Brazil, on the 10th October 2018. This species is of high local economic interest in Northeast Brazil, and this picture illustrates that potential nurseries overlap with fishing grounds in the Amazon region (© Rodrigo Barreto).

Carcharhinus leucas is found in nearshore, marine waters, but also penetrates low-salinity habitats (Thorson, 1982), particularly during early life history stages (Pillans, 2006; Heupel, Simpfendorfer, 2008; Curtis *et al*., 2011; Matich, Heithaus, 2012; Niella *et al*., 2022). This behavior promotes juvenile survival by reducing predation risk (Heupel, Simpfendorfer, 2011; Lofthus *et al*., 2024), but increases their susceptibility to human impacts (Simpfendorfer, Burgess, 2005; Kyne *et al*., 2012). In Latin America, *C. leucas* is known to occur in > 90 specific locations with fresh and brackish water conditions (Gausmann, 2021). However, the use of low-salinity habitats is not homogenous, with only 13 rivers, lakes, estuaries, and lagoons reported as *C. leucas* habitat in the Pacific compared to 78 in the Atlantic (Gausmann, 2021), reflecting geographic differences in topography, and the conservation value of freshwater habitats connected to the Pacific due to their paucity (*e.g*., De la Llata Quiroga *et al*., 2023).

Thomas B. Thorson was a pioneer in studying freshwater elasmobranchs in Central America and devoted his career to this research, with special emphasis on *C. leucas* (an extensive bibliography of Thorson's lifetime work was compiled by Pollerspöck, Straube, 2024). Thorson's work on sharks in Latin America ended in the 1980s, partly due to the increasing political crisis in many countries, which made research in this region challenging. Research on *C. leucas* in the freshwater systems of Latin America have since been limited (Oliveira *et al*., 2023), with many unresolved research questions. There is currently no data available on the distribution and habitat use of euryhaline sharks and sawfish for most freshwater and brackish systems of Latin America, which hinders an assessment of their conservation status and the implementation of successful conservation measures. Blaber, Barletta (2016) highlighted this data gap, and despite the increasing number of Latin American chondrichthyan studies over the past decade, there is still a need to redirect efforts toward specific research areas, regions, and species that currently show major information gaps like *C. leucas* in freshwater and brackish systems (Espinoza *et al*., 2018). Becerril-García *et al*. (2022) recently outlined important research priorities for the conservation of chondrichthyans in Latin America, emphasizing the need to assess freshwater ecosystems more comprehensively as elasmobranch habitats. In addition to overfishing, the identification of other anthropogenic threats as well as those posed by the environment is of special concern for freshwater chondrichthyan conservation in Latin America, because of extensive habitat alterations and deteriorations across the region (Reis *et al*., 2016). Population assessments of euryhaline and freshwater elasmobranchs are scarce (Jorgensen *et al*., 2022), thereby increasing the challenge of assessing the consequences of these threats.

Our study identifies research areas of top priority for *C. leucas* in Latin America based on data gaps identified from a review of the literature, published media, and recommendations from researchers across the region. This survey focuses on seven sites of interest in Mexico, Guatemala, Nicaragua, Panama, Venezuela, and Brazil, because of their biogeographical importance and/or reproductive significance for *C. leucas*, with the goal of not only highlighting research questions of special concern, but broadly rekindling interest in 'sharks in fresh waters of Latin America' among the scientific community, with a focus on updating the status of locations in Latin America that have been historically identified as crucial for *C. leucas* but are now understudied and largely unprotected.

MATERIAL AND METHODS

Study area. The study area includes all countries of continental Latin America as well as the biggest island states of the Greater Antilles that lie within the distribution of *Carcharhinus leucas*. Chile and mainland countries such as Bolivia and Paraguay where *C. leucas* does not occur were excluded. Latin America is broadly defined here to include not only Spanish and Portuguese-speaking countries, but countries with other official languages in the neotropics, including Guyana, Suriname, French Guyana, and Belize. As such, the study area spans the waters of the Tropical Eastern Pacific from Mexico to Peru and the western Atlantic Ocean from Mexico to northern Argentina (estuary of the Río de la Plata), consisting of the following 23 countries and overseas territories populated by ~665 Mio. people (Statista Inc., 2022): Argentina, Belize, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, French Guyana, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Peru, Puerto Rico, Suriname, Uruguay, Venezuela (Fig. 2).

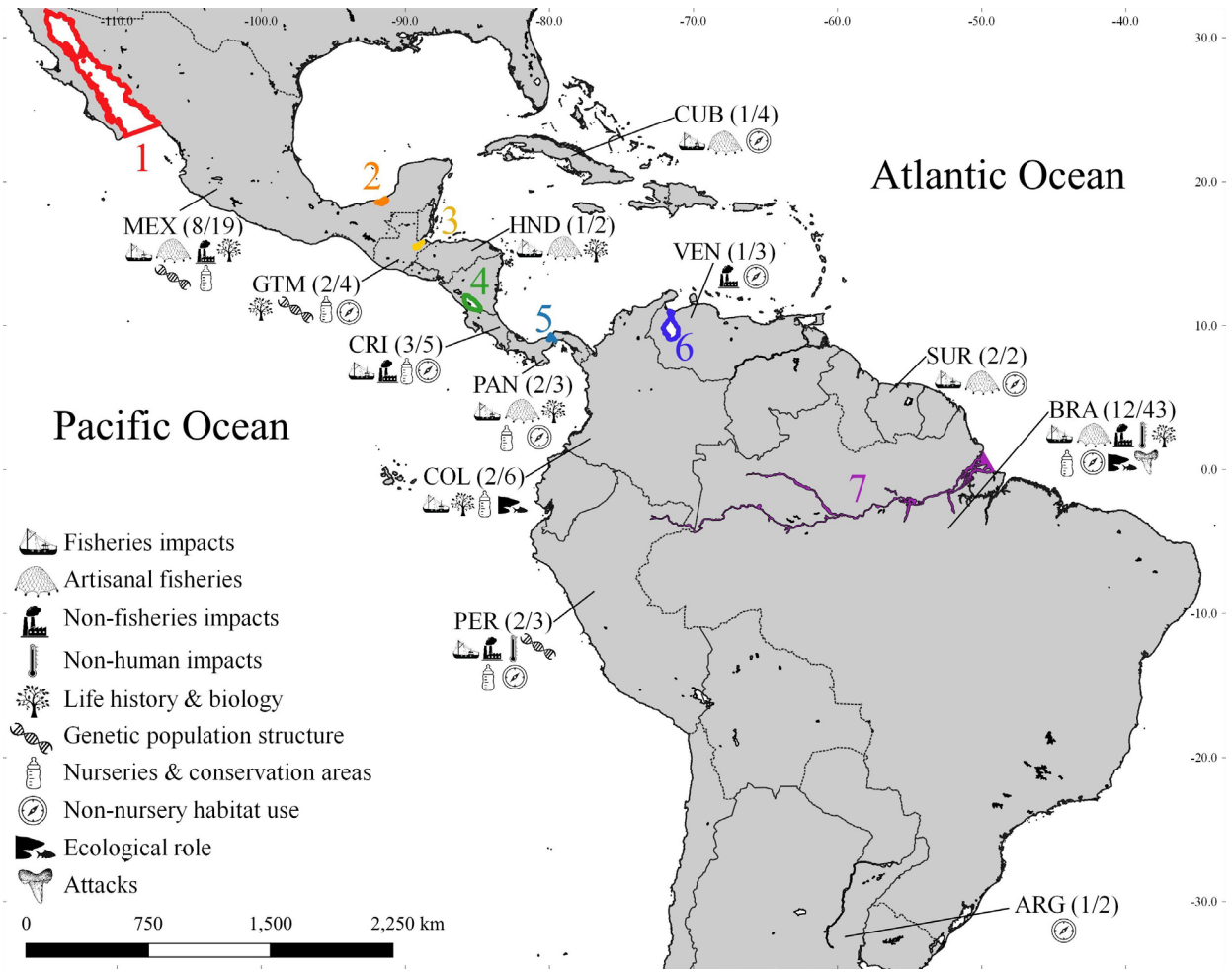

FIGURE 2 | Distribution of research goals for *Carcharhinus leucas* in Latin America based on scientist interviews. Numbers in brackets after the country abbreviations = numbers of responding scientists in relation to requested scientists for each country; colored numbers represent sites of special scientific concern: 1 (red) = Gulf of California, 2 (orange) = Terminos Lagoon, 3 (yellow) = Lake Izabal-Dulce River system, 4 (green) = Lake Nicaragua-San Juan River system, 5 (blue-green) = Panama Canal and Lake Gatun, 6 (blue) = Lake Maracaibo, 7 (purple) = Amazon River system.

Expert surveys. To understand the perspective of local experts, shark scientists across Latin America (n = 110; Tab. **S1**) were solicited similar to Hays *et al*. (2016). Due to the paucity of experts in some Latin American countries, we did not set a threshold of publications on the topic of "sharks" in general and "*Carcharhinus leucas*" in particular for the scientists we asked. Therefore, all experts who had at least one publication on this topic were considered for the survey. Some of the experts involved derived from recommendations from other requested Latin American experts. Each scientist was asked to provide research goals that would improve knowledge on *C. leucas* in their study area:

1. In your opinion, what topic or aspect regarding *Carcharhinus leucas* should be investigated, and which research goal should be prioritized?
2. Based on your expertise, which location(s) are priorities for this research?

Responses were compiled and grouped based on respective research topics and similarities (see Results; Tab. 1). More than half of the Latin American countries were represented by at least one expert (see Results; Tab. **S1**), however, several countries, particularly those with small populations (*e.g*., Haiti, Dominican Republic, Puerto Rico, El Salvador, Belize), did not have any experts respond (Tab. **S1**).

Literature review, investigation of online media and museum records. To complement the recommendations from Latin American scientists, a literature review was conducted in Google Scholar, Scopus, and Web of Science using relevant key words in English, Spanish, and Portuguese pertaining to *C. leucas* in Latin America (*e.g*., "Carcharhinus leucas"; "Latin America"; "tiburon toro"; "tubarão-cabeça-chata"; "freshwater"; "agua dulce"; "água doce"). Results were compiled to derive locations that are currently or were historically important for *C. leucas*. We filtered these results based on our knowledge of critical habitats of this species, resulting in seven sites we

TABLE 1 | Research goals for *Carcharhinus leucas* based on responses from Latin American scientists.

Nº	Research goal	Number of answers
1	Non-nursery habitat use and distribution (incl. migration)	25 (68%)
2	Life history and biology (*e.g*., age and growth, reproduction, population dynamics)	18 (49%)
3	Fisheries impacts	17 (46%)
4	Identification of nurseries and other conservation areas	16 (43%)
5	Non-fisheries human impacts (*e.g*., habitat degradation, pollution)	15 (41%)
6	Occurrence in artisanal fisheries	10 (27%)
7	Genetic population structure	4 (11%)
8	Ecological role	4 (11%)
9	Non-human impacts (*e.g*., climate change, extreme climate events, lack of prey)	3 (8%)
10	Shark bites	1 (3%)

considered most important for the life history of *C. leucas* and crucial for maintaining stable populations in Latin America. These seven sites compose the Gulf of California, Terminos Lagoon, Lake Izabal-Dulce River system, Lake Nicaragua-San Juan River system, Panama Canal and Lake Gatun, Lake Maracaibo, and the Amazon River system (Tab. 2; Fig. 2).

Published data and historic records play a pivotal role in assessing species status, with inferences on occurrence or extirpation generally based on past observations in the absence of long-term monitoring data (Rivadeneira *et al*., 2009). Thus, an extensive review and synthesis of historic records, media reports (newspapers, social media, and networks; Tab. **S2**), and museum specimens (Tab. **S3**) were also included to supplement data from scientific literature. Online media references underwent a critical check on their reliability based on published literature and known information pertaining to *C. leucas* (*e.g*., morphology, behavior). For each location, ecosystem characteristics and a short chronological summary of research conducted on sharks were composed, including the present state of knowledge. The derivation of important research questions for *C. leucas* in Latin America, including those for the seven sites we identified to be of top priority, is summarized in the results and discussion section.

All size measurements and estimations of length of *C. leucas* specimens reported and recorded at these sites are provided in cm total length (TL). Museum and institutional abbreviations of voucher specimens housed in collections are described in the following format according to Sabaj (2020): CAS-SU: California Academy of Sciences, Ichthyological Collection, incl. specimens from the historical collection of Stanford University (SU), San Francisco; CMNFI: Canadian Museum of Nature, Fish Collection, Ottawa; MCZ: Museum of Comparative Zoology, Harvard University, Cambridge; MOVI: Museu Oceanográfico do Vale do Itajaí, Santa Catarina; NMW: Naturhistorisches Museum, Wien; TCWC: Texas Cooperative Wildlife Collection, Texas A&M University, College Station, Texas; TU: Royal D. Suttkus Fish Collection, Tulane University Biodiversity Research Institute (TUBRI), New Orleans; UCLA:

TABLE 2 | Localities of scientific concern for *Carcharhinus leucas* in Latin America based on the results of literature review conducted by the authors as well as their own experiences. Numbers with asterisk = locations that were also mentioned by the interviewed Latin American scientists.

Nº	Locality toponym	Country	Geographical coordinates / spatial extension	Regional climate conditions
1*	Gulf of California	Mexico	31.70°N, -114.80°W to 24.30°N, -107.50°W	Subtropical
2	Terminos Lagoon	Mexico	18.50°N, -91,85°W to 18.80°N, -91.29°W	Tropical
3	Lake Izabal-Dulce River system	Guatemala	15.36°N, -89.32°W to 15.81°N, -88.75°W	Tropical
4	Lake Nicaragua-San Juan River system	Nicaragua / Costa Rica	12.09°N, -85.87°W to 10.79°N, -83.58°W	Tropical
5*	Panama Canal and Lake Gatun	Panama	9.27°N, -79.91°W to 8.97°N, -79.58°W	Tropical
6*	Lake Maracaibo	Venezuela	10.99°N, -71.60°W to 9.03°N, -71.61°W	Tropical
7*	Amazon River system	Brazil / Colombia / Peru	0.70°N, -50.19°W to -8.37°S, -74.52°W	Tropical

University of California at Los Angeles, Los Angeles; UCR: Museo de Zoología, Escuela de Biología, Universidad de Costa Rica, San Pedro de Montes de Oca; USNM: Smithsonian Institution National Museum of Natural History, Washington, D.C.

RESULTS AND DISCUSSION

Expert surveys. Thirty-seven scientists from twelve countries across Latin America provided research recommendations and goals for *Carcharhinus leucas* in the region (34% response rate; Tab. **S1**). Most of the responding researchers originated from Brazil (n = 12) and Mexico (n = 8), with fewer responding scientists from smaller Latin American countries (Tab. **S1**). Responses were organized into 10 main topics (Tab. 1). Most responding scientists provided multiple recommendations, highlighting that information is lacking for many aspects of *C. leucas* in Latin America. Scientists often cited a lack of resources (*i.e.*, funding) for research, and therefore data limitations, as the primary contributor to research goals.

Summarized, the interactions fisheries have with *C. leucas* was the most frequently noted priority (Tab. 1, number 3 and 6; Fig. 2), including missing information on landings data, time series analysis of catch per unit effort (CPUE), and catch composition (*e.g.*, sex ratio, sizes, maturity stages). Fisheries impact (46%) and occurrences of *C. leucas* in artisanal fisheries (27%) can be counted together and represent 73% of scientists who highlighted fisheries concerns. Data gaps create a barrier to assessing the sustainability of fishing, and fisheries monitoring and management efforts are very limited in some regions (*e.g.*, northeast Brazil) based on responses, hindering efforts to address other priorities if *C. leucas* continues to be overfished. Scientists reported that a stock assessment is a key first step to addressing fisheries impacts, along with outreach efforts with local communities to assess artisanal fisheries via local ecological knowledge. Fishing activities, particularly near key nursery habitats and those that coincide with times of reproduction, were identified as serious threats, and despite *C. leucas* not being a target species in many countries, bycatch was a concern for 20 scientists (54%). Fisheries data plays a key role in elasmobranch research in the region, thus a stronger relationship between scientists, fisheries managers, and fishing communities is clearly needed.

The evaluation and elimination of other threats was a priority for 49% of scientists, including habitat degradation due to pollution, coastal development, and climate change. *Carcharhinus leucas* life history and biology (49%) and genetic population structure (11%) were reported as data gaps in Latin America, however, understanding habitat use and identifying key areas for conservation, including potential nurseries, was of greater interest for most of the responding scientists (non-nursery habitat use: 68%; identification of nurseries and other conservation areas: 43%; Tab. 1). Prioritizing studies that assess distribution and habitat value overlap with understanding fisheries and non-fisheries impacts, because if essential habitat can be identified, then fisheries and land use regulations could be enacted that help protect these areas. Surprisingly, only one scientist (3%) based in Pernambuco, Brazil, identified shark bites as a research goal attributed to several incidents along the beaches of Recife between 1992 and 2006 (*e.g.*, Hazin *et al.*, 2008).

The impact of fisheries and *C. leucas* distribution were nearly ubiquitous priorities, but other topics varied based on the residence of responding scientists (Fig. 2). Non-fisheries threats (41%) were only recognized by respondents from five countries. Life history and biology (49% of the responding scientists) was a priority for half of the representative countries, while *C. leucas* population genetics (n = 3 countries) and ecological role (n = 2 countries) were among the least prioritized. Countries with multiple responding scientists exhibited geographic differences in priorities (Tab. **S4**), as well as locations within their respective countries that should receive attention. In Mexico, there was a clear focus on the Gulf of California, particularly Southern Baja California, Cabo Pulmo, Sinaloa to Nayarit, and the Yucatan Peninsula. Costa Rican scientists highlighted the Gulf of Nicoya, Nicoya Peninsula, and the Coyote Estuary, because of potential *C. leucas* nurseries. The Panama Canal was identified by Panamanian scientists as an area of interest where sport fishers capture juvenile bull sharks in considerable numbers, and a future tagging program in cooperation with these fishers is planned. Lake Maracaibo and the adjacent Gulf of Venezuela were of special concern, because of pollution and habitat degradation caused by oil spills, wastewater, and harmful algal blooms, and the lack of recent data on *C. leucas* distribution and habitat use. Surinamese scientists indicated that *C. leucas* is rare in their country despite favourable habitats, including the Coppename, Maroni, and Suriname Rivers and their estuaries, which could be attributed to overfishing and/or the need to use less traditional monitoring methods such as measuring environmental DNA (eDNA) for successful occurrence verification. Brazilian scientists also highlighted the considerable lack of information on *C. leucas* in their country despite extensive areas of suitable habitat, particularly freshwater systems and tributaries of the Amazon, São Francisco, and Doce Rivers and their respective deltas that may be important nursery habitat. Sixteen (43%) scientists prioritized the identification of *C. leucas* nursery areas, but none suggested a re-assessment of historic, but overexploited nurseries in Lake Izabal and Lake Nicaragua.

Literature review

Gulf of California. *Carcharhinus leucas* was first described in the Gulf of California (= Sea of Cortez; Fig. 3) by Rosenblatt, Baldwin (1958), who reported its distribution in the East Pacific from southern California, USA to Guayaquil, Ecuador. This species has been part of Mexican commercial fisheries in the northern Gulf of California and Gulf of Tehuantepec (Bonfil, 1994), but its abundance has declined through time, which is a result of overfishing, habitat deterioration, and naturally low availability of potential nursery habitat in the region (Galván-Magaña *et al*., 1989, 1996; Bizzarro *et al*., 2009; Saldaña-Ruiz, 2017; Saldaña-Ruiz *et al*., 2017). Due to the low number of rivers that drain into the Gulf of California, there is limited freshwater inflow from the Colorado, Fuerte, Mayo, Sinaloa, Sonora, and Yaqui Rivers. The Colorado River was the largest source of freshwater before its use for irrigation and water storage (Schmidt *et al*., 2023). Today, the Colorado River no longer reaches the sea most years (Schmidt *et al*., 2022), which has undoubtably altered its function as *C. leucas* habitat. Hastings, Findley (2006) and Bonfil (2014) mentioned the occurrence of *C. leucas* near the Colorado River Delta, and it is plausible that this location was a potential nursery ground for bull sharks in the past, but its status fulfilling this function is currently unknown (Gausmann, 2021).

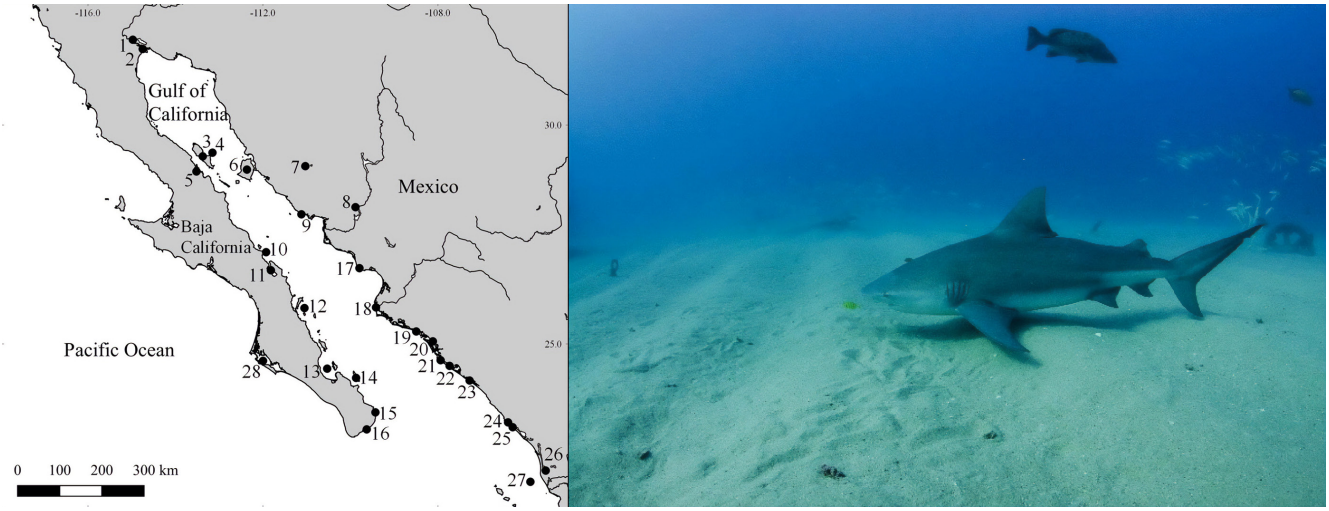

FIGURE 3 | The Gulf of California is considered an area of special scientific concern for *Carcharhinus leucas* in the Northeast Pacific Ocean. At the marine reserve of Cabo Pulmo National Park (Baja California Sur; site 15), subadults and adults are frequently encountered, but small juveniles do not occur at this site (© Leonardo Gonzalez). 1) Colorado River, 2) Colorado River Delta Biosphere Reserve, 3) Isla Angel de la Guarda, 4) Deep benthic midriff islands, 5) Bahia de los Angeles, 6) Isla Tiburon, 7) Rio Sonora, 8) Rio Yaqui, 9) Bahia los Algodones, 10) Mulege-Santa Rosalia, 11) Bahia Concepcion, 12) Bahia de Loretc National Park, 13) Bahia de la Paz, 14) Cerralvo Island, 15) Cabo Pulmcg National Park, 16) Cabo San Lucas, 17) Rio Mayo, 18) Rio Fuerte, 19) Rio Sinaloa, 20) Bahia de Santa Maria- La Reforma, 21) Altata-Ensensada (Lazoon Suster, 22) Culiacan River, 23) Bahia la Guadalupana, 24) Urias Lagoon, 25) Presidio River, 26) Teacapan-Agua Brava Lagoon-Estuarine System. 27) Zona Marina de la Isla Isabel, 28) Bahia Magdalena.

Beyond the Colorado River Delta, the Gulf of California contains other important conservation areas, including Cabo Pulmo National Park and Bahía de Loreto National Park (SEMARNAT, 2018). *Carcharhinus leucas* inhabits both national parks (Reyes-Bonilla *et al*., 2016; Lara-Lizardi *et al*., 2022, 2024), as well as the Presidio River (Castro-Aguirre, 1978; Castro-Aguirre *et al*., 1999; Espinosa-Pérez *et al*., 2004; Miller *et al*., 2006, 2009), Bahía Concepción and the Bahía Magdalena-Almejas lagoon system (Gonzáles-Acosta *et al*., 2015, Rábago-Quiroz *et al*., 2024), the Altata-Ensenada Lagoon system, and Urias Lagoon (Gausmann, 2021). Regionally, 14 Important Shark and Ray Areas (ISRAs) for elasmobranch conservation have been designated in the Gulf (Jabado *et al*., 2023), with *C. leucas* and other sharks suspected to give birth in some of these ISRAs (Salomón-Aguilar *et al*., 2009).

Carcharhinus leucas expectantly exhibits variability in its distribution in the Gulf of California based on size, with the Presidio River, Altata-Ensenada Lagoon system, Urias Lagoon, and Teacapán-Agua Brava system serving as juvenile habitats (Applegate *et al*., 1993; Ruelas-Inzunza, Páez-Osuna, 2005, 2007; Bizzarro *et al*., 2009; Ruelas-Inzunza *et al*., 2014; Salomón-Aguilar *et al*., 2009; Gausmann, 2021). Data on size classes and habitat use of *C. leucas* in these systems are, however, largely lacking, preventing formal nursery assessments according to Heupel *et al*. (2007). Additionally, Ramirez-Amaro *et al*. (2013) reported on a juvenile *C. leucas* south of Bahia Magdalena, indicating that potential nursery(ies) could also be located northwest of Cabo Pulmo, but only subadult and adult *C. leucas* are found at Cabo Pulmo National Park (Lara-Lizardi *et al*., 2022, 2024). Lara-Lizardi *et al*. (2022, 2024) observed sex-based differences in *C. leucas*

distribution at Cabo Pulmo, with females showing higher residency than males in most seasons, but departing in summer-fall presumably migrating for parturition because there is no source of freshwater inflow nearby suitable for juvenile habitat.

Terminos Lagoon. Terminos Lagoon, located in the Mexican state of Campeche, is one of the most important hydrological networks of the country (Diario Oficial de la Federación, 1997; Soto-Galera *et al*., 2010) and the largest coastal lagoon in the southern Gulf of Mexico (Yáñez-Arancibia *et al*., 1980; Medina-Gómez *et al*., 2015). This lagoon is a complex eco-social system, where a high biodiversity (aquatic and terrestrial) coexists with important economic and social sectors, such as tourism, hydrocarbon industry, and fisheries (Medina-Gómez *et al*., 2015; Campos Flores, Crespo Guerrero, 2018). Despite its designation as a Mexican Protected Area since 1994 (Diario Oficial de la Federación, 1994), pollution deriving from oil spills and contamination with heavy metals poses a potential threat to the local ecosystems (Montalvo *et al*., 2014; Olivares-Rubio *et al*., 2024). Several environmental changes and species turnovers have been reported through the years at this site (Ramos-Miranda *et al*., 2005; Soto-Galera *et al*., 2010; Medina-Gómez *et al*., 2015; Paz-Ríos *et al*., 2021).

The presence of *Carcharhinus leucas* in the lagoon was first reported by Castro-Aguirre (1978) (Tab. 3). In Uribe's (1993) thesis, he found that *C. leucas* and *Sphyrna tiburo* (Linnaeus, 1758) (bonnethead shark) were the most abundant shark species in this estuary system (41.2% and 35.3% of catches, respectively). Uribe reported neonates and juveniles for both species (immature *C. leucas* ranging between 71–102 cm TL). A study

TABLE 3 | Summary of locations of special interest regarding scientific research on *Carcharhinus leucas* in the Latin American region as identified by the authors with research goals and suggested investigation methods. Numbers with asterisk = locations that were also mentioned by the interviewed Latin American scientists.

Nº	Toponym	Year of the first record of *Carcharhinus leucas*	Research topic	Research goals	Research and investigation methods
1*	Gulf of California	1958	Reproduction	Identification of coastal nursery areas	Acoustic or satellite tracking, tagging
2	Terminos Lagoon	1978	Reproduction	Verification of the use of a nursery / estimation of population size / impacts of water pollution / development of appropriate educational tools targeting shark conservation	Catch per unit effort (CPUE), acoustic or satellite tracking, tagging, DNA sampling, local ecologically knowledge (interviews with local fishermen), tissue sampling
3	Lake Izabal-Dulce River system	1948	Reproduction	Verification of the use of a nursery / estimation of population size	Catch per unit effort (CPUE), acoustic or satellite tracking, tagging, DNA sampling, local ecologically knowledge (interviews with local fishermen)
4	Lake Nicaragua-San Juan River system	1877	Reproduction	Verification of the use of a nursery of regional significance / estimation of population size	Catch per unit effort (CPUE), acoustic or satellite tracking, tagging, local ecologically knowledge (interviews with local fishermen)
5*	Panama Canal and Lake Gatun	1948	Biogeography, genetics, distribution	Verification of possible canal passage and possible transfer of specimens; genetic sampling from specimens of Atlantic and Pacific origin	Environmental DNA (eDNA), fishing (gill net, hook and line) in both the canal and the lakes, tagging of marine Atlantic and Pacific specimens in the vicinity of the canal, ongoing DNA clustering of marine Atlantic and Pacific populations for confirmation of gene admixture
6*	Lake Maracaibo	1964	Reproduction	Verification of the use of a nursery / estimation of population size	Acoustic or satellite tracking, tagging, DNA sampling, local ecologically knowledge (interviews with local fishermen)
7*	Amazon River system	1913	Reproduction	Estimation of habitat use / confirmation of a nursery / impact of river impediments	Acoustic or satellite tracking, tagging, local ecologically knowledge (interviews with local fishermen)

on sharks outlined Campeche as the principal state for captures of *C. leucas*, including the main fishing ports such as Caleta (Ciudad del Carmen; Fig. 4), Isla Aguada, and Sabancuy located within Terminos Lagoon or in its near vicinity (Castillo-Géniz *et al*., 1998), indicating that potential nursery areas of *C. leucas* overlapped with areas of intensive fishing activities

Carcharhinus leucas has been one of the principal species captured in the southern Gulf of Mexico artisanal fisheries for decades (Castillo-Géniz *et al*., 1998; Pérez-Jimenez *et al*., 2012, 2016; Pérez-Jimenez, Mendez-Loaeza, 2015; Figs. 1, 4). It is both targeted and caught as bycatch year-round (Pérez-Jimenez, Mendez-Loaeza, 2015), with all life stages at risk: newborns, juveniles, adults, and pregnant females (Pérez-Jiménez *et al*., 2020). A recent study by Pérez-Jiménez, Mendoza-Carranza (2023) documented high proportions (> 90%) of immature sharks across approximately 12 species in the artisanal fisheries of Tabasco and Campeche. These findings highlight the coastal waters of both states, including Terminos Lagoon, as potential nursery habitats for juvenile sharks such as *C. leucas*.

Further targeted research is necessary to assess the current role of this lagoon as a nursery for *C. leucas*. Documented bull shark declines in the Gulf of Mexico (Pérez-Jiménez *et al*., 2012) and the nearby Mexican Caribbean (Rubio-Cisneros *et al*., 2023) appear to be driven by a combination of fishing pressure, pollution from the oil industry particularly in Terminos Lagoon (Campos Flores, Crespo Guerrero, 2018; Peña-Puch *et al*., 2021), and changes in water quality parameters such as temperature, salinity, and dissolved oxygen. It is known that *C. leucas* also uses smaller lagoons in the western part of the Terminos Lagoon system, including Pom Lagoon and Atasta Lagoon (D. Lon, 2021, pers. comm.).

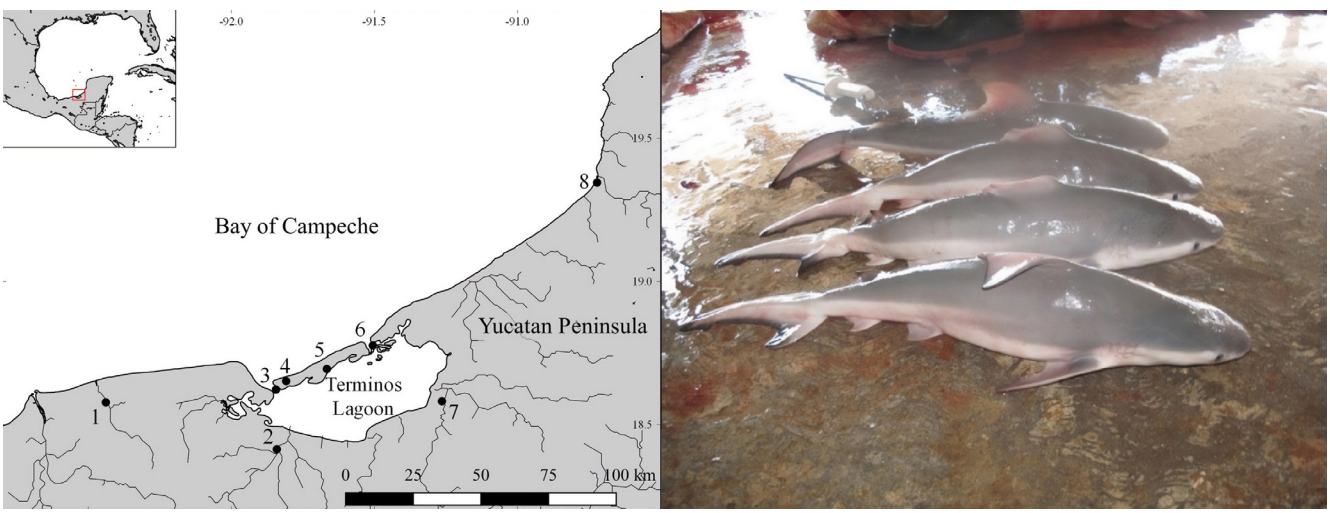

FIGURE 4 | Terminos Lagoon is an important nursery site for *Carcharhinus leucas* in the southern Gulf of Mexico. However, at this site, the local population is at risk from fisheries, environmental pollution, and habitat change. These small juvenile *C. leucas* were landed at the port of Ciudad del Carmen (© Nadia Sandoval Laurrabaquio-Alvarado). 1) Usumacinta River, 2) Palizada River, 3) Boca del Carmen, 4) Ciudad del Carmen, 5) Isla del Carmen, 6) Boca de Puerto Real, 7) Candaleria River, 8) Champoton.

Recently, an anomalous embryo (46.5 cm TL) showing synophthalmia (a rare congenital malformation in which the eyelids and eyes partially or completely fuse together to form a single orbital insert in the center of the face) and leucism was registered in a pregnant *C. leucas* that was captured in marine waters between the mouth of the Grijalva River and Terminos Lagoon (Wakida-Kusunoki *et al*., 2022). According to these authors, this anomaly, among other factors, can be related to the environmental pollution in this area. However, the possibility of genetic damage due to inbreeding resulting from a very low population size as a consequence of overfishing cannot be excluded.

Lake Izabal-Dulce River system. The first scientific record of *Carcharhinus leucas* from the Lake Izabal-Dulce River system (and from Guatemala) was described by Bigelow, Schroeder (1948), who reported two specimens (69.2 cm TL, ♀; 91.5 cm TL, ♀, USNM 134326; Fig. 5; Tab. **S3**) similar in size to those reported by Thorson *et al.* (1966; 69.4, 70.1, 108.8, and 120 cm TL, sex undetermined, uncataloged), and Garrick (1982; 127 cm TL, ♀, USNM 146542). Lake Izabal is the third largest lake in Central America (717 km²), which drains into the Caribbean Sea via the 40 km Dulce River (Thorson *et al*., 1966). For part of its length, the Dulce River expands into a small lake (El Golfete), which functions as an estuary based on saltwater incursion, making it appropriate habitat for euryhaline fish like juvenile *C. leucas* (Saunders *et al*., 1950). The sizes of all reported and collected *C. leucas* specimens were juveniles (Fig. 5; Tab. **S3**), indicating the Lake Izabal-Dulce River system functioned at least historically as a nursery before overfishing began in the 1960s.

Thorson *et al*. (1966) reported claims from residents that sharks occurred abundantly throughout the Dulce River and Lake Izabal, and up the Polochic River. Michot *et al*. (2002) and Alvarado *et al*. (2005) highlighted that *C. leucas* was historically distributed from El Estor to San Felipe, and thereby used the entire system. However, Brinson (1973) described severe declines and a noticeable reduction in the abundance of *C. leucas*, with no reports of sharks shortly after (Brinson, Nordlie, 1975). Guatemala's Fundación Defensores de la Naturaleza (2002) more recently reported the extirpation of *C. leucas* in both Polochic River and Lake Izabal, and Hacohen-Domené *et al*. (2020) did not record *C. leucas* in the artisanal elasmobranch fisheries at Livingston, Guatemala's Caribbean coast. It is currently unknown if and how *C. leucas* use the Lake Izabal-Dulce River system, but one juvenile *C. leucas* was recently seen swimming at the surface of Lake Izabal (Tab. **S2**).

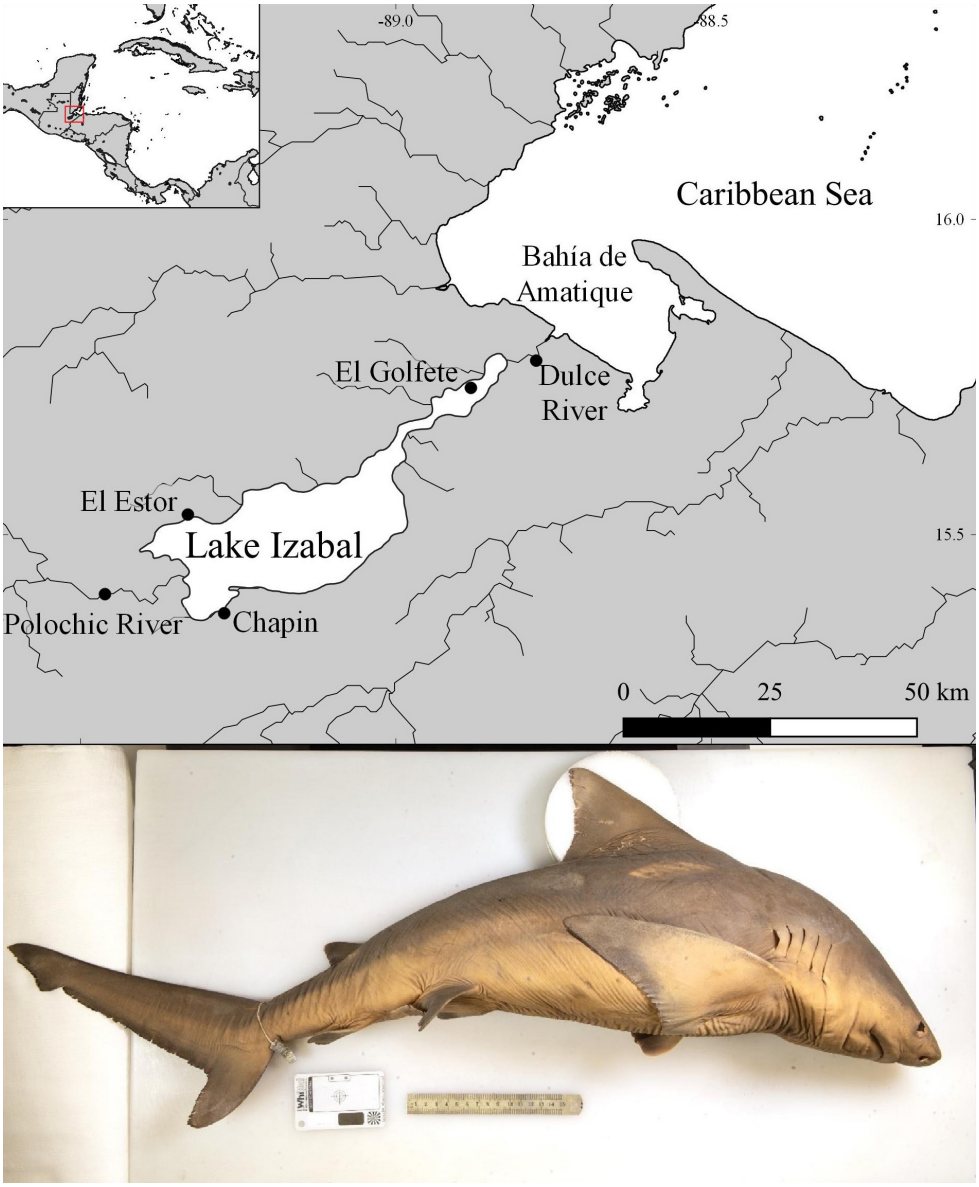

FIGURE 5 | The Lake Izabal-Dulce River system is an area of special scientific concern for *Carcharhinus leucas* in Central America. At this site, *C. leucas* was already fished out in the 1970s. The recorded juvenile specimens from this site indicate that Lake Izabal was a nursery for *C. leucas*, which is supported by collected material such as this specimen (USNM 134326: ♀, 91.5 cm TL) from 1946 collected at the northeast drainage by R. R. Miller (© Smithsonian Institution).

Lake Nicaragua–San Juan River system. The history of Lake Nicaragua and the culture of its people are indivisible linked to *Carcharhinus leucas* (Peréz, Mondragón, 2011). Early Spanish historiographers made observations of sharks in the 16th Century (Burke, 1979), and the first scientific report of sharks in Lake Nicaragua was made by Gill, Bransford (1877), which were very abundant (Smith, 1893), and likely the largest freshwater population of *C. leucas* in the world (Thorson, 1982). Lake Nicaragua is the third-largest lake in Latin America (7,897 km^2), and it drains into the Caribbean Sea via the San Juan River, both of which were *C. leucas* habitat (Thorson, 1982; Fig. 6).

The Lake Nicaragua-San Juan River system historically harbored a diversity of marine ichthyofauna, including *C. leucas*, *Pristis pristis* (Linnaeus, 1758) (common sawfish), and *Megalops atlanticus* (Lacepède, 1803) (Atlantic tarpon). From the 1960s–1980s, Thomas B. Thorson studied *C. leucas* in this extensive nursery (Astorqui, 1967), where sharks once migrated between freshwater habitats of Lake Nicaragua to the marine environments of the Caribbean Sea (Hagberg, 1968; Thorson, 1970a,b, 1971, 1972a, 1976, 1982; Tuma, 1976; Watson, Thorson, 1976). However, unsustainable fishing practices changed this. Nicaragua was the first country where commercial exploitation of sharks took place in Central America, including Lake Nicaragua and the San Juan River, beginning in the 1940s (Rojas *et al*., 2000). In the 1960s–1970s, Japan established a shark fin processing plant on the shores of the San Juan River and Lake Nicaragua at Granada, which exported *C. leucas* and *P. pristis* fins to China, Taiwan, Hong Kong, and Singapore (Davies, Pierce, 1972; Peréz, Mondragón, 2011; Contreras-MacBeath *et al*., 2024). Despite unsustainable fishing, Hagberg (1968) found *C. leucas* and *P. pristis* in considerable numbers in the late 1960s, but both species declined at alarming rates in the 1970s, leading to their near extirpation in the early 1980s (Astorqui, 1974; Thorson, 1982; Rojas *et al*., 2000; Martínez-Sánchez *et al*., 2001; Bustamante, Lamilla, 2006; Zarate, Hearn, 2008). Research expeditions to Lake Nicaragua during the 1990s-2000s consequently failed to find *C. leucas* or they were observed in very low numbers (Taniuchi, 1992, 2002; Tanaka, 1994; McDavitt, 2002; Zarate, Hearn, 2008).

The Nicaraguan government instituted a temporary moratorium on targeted fishing for sawfish and sharks (Thorson, 1982), and later declared them as prohibited species by national law (McDavitt, 2002), but this measure likely came too late (Zarate, Hearn, 2008). *Carcharhinus leucas* have been observed in Lake Nicaragua since 2000 (Martínez-Serrano *et al*., 2014; Información Puntual, 2020; Tab. **S2**), which may indicate site fidelity to this system. However, *C. leucas* of Lake Nicaragua have not recovered. Sharks no longer play a role in Lake Nicaragua fisheries, and individual sharks are only occassionally caught as bycatch in gillnets targeting other species. Nicaragua Investiga (2022) reported that bull sharks have only been sighted in the Lake Nicaragua-San Juan River system sporadically for decades, including two recent observations in 2020 from Zapatera Island.

Beyond the era of Thorson's research, data and information about the occurrence and abundance of *C. leucas* from this locality is scarce (*e.g*., Astorga, 2023; Angulo *et al*., 2023). Most sharks studied from this system were immature, indicating its function as a nursery (Tab. **S3**). Extreme abundances of juveniles in the Lake Nicaragua-San Juan River system, coupled with a recently described distinct lineage of *C. leucas* in the Caribbean Sea (Laurrabaquio-Alvarado *et al*., 2021), indicate that this system could have been one of the most important nurseries for *C. leucas* in the region. In Nicaragua, scientific research on elasmobranchs currently focuses on the Pacific Ocean, with no attention given to the freshwater elasmobranchs of Lake Nicaragua due to limited funding (*e.g*., Hernández-Fernández *et al*., 2021; G. M. Hernández-Fernández, 2023, pers. comm.).

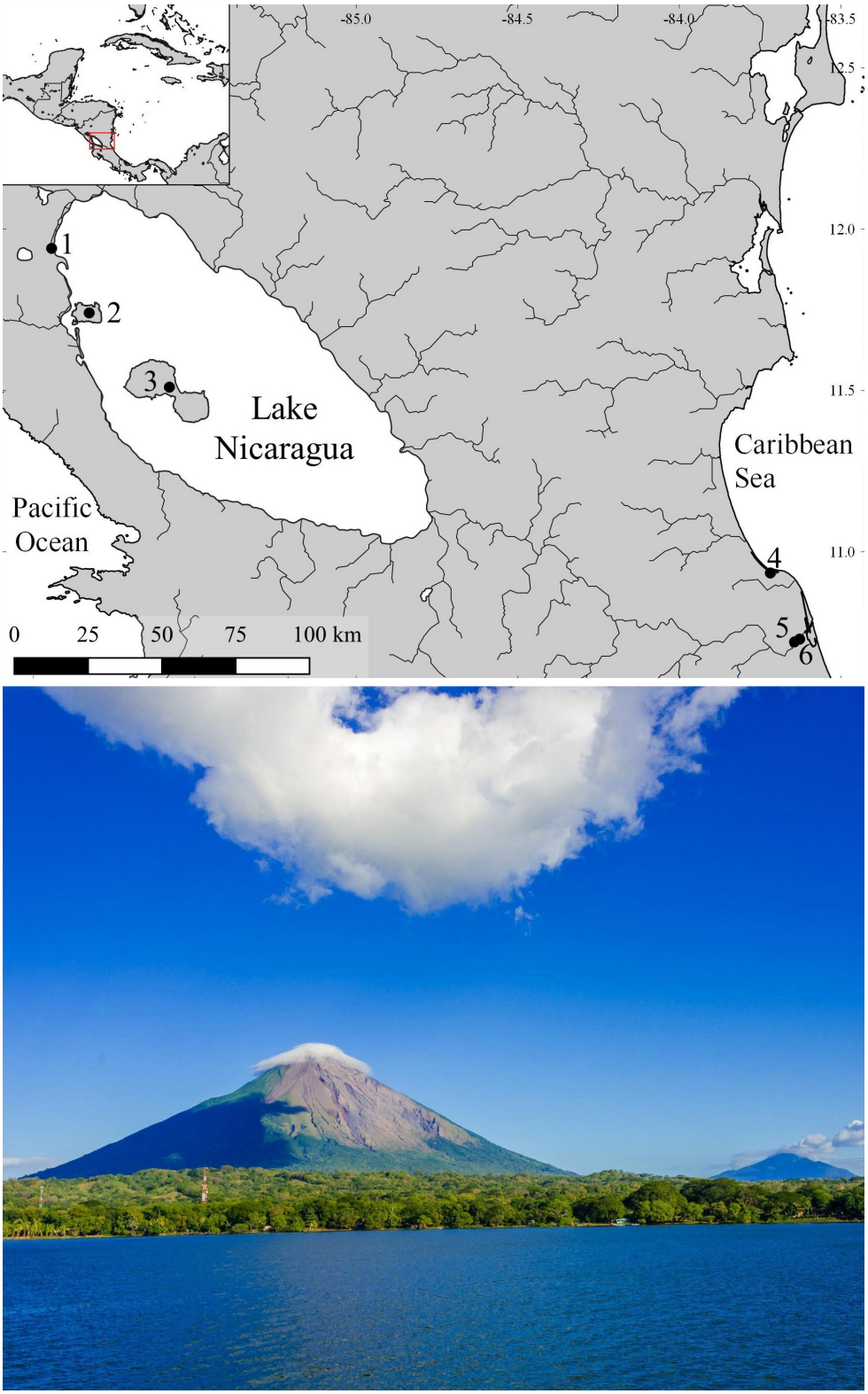

FIGURE 6 | The Lake Nicaragua-San Juan River system was historically the most important nursery for *Carcharhinus leucas* in the entire Caribbean region (© Simon Dannhauer). 1) Granada, 2) Zapatera Island, 3) Ometepe Island, 4) San Juan del Norte, 5) San Juan River, 6) Colorado River.

Panama Canal and Lake Gatun. The 82 km Panama Canal connects the Caribbean Sea and the Tropical East Pacific (Fig. 7), which had been disparate and impassable for marine biota since the emergence of the Isthmus of Panama ~3,5 myr ago, until 1914 when the canal was completed (Coates, Stallard, 2013). As a euryhaline shark, the low-salinity waters of the Panama Canal should provide no physiological barrier to *C. leucas* (Misra, Menon, 1955). However, there is only one verifiably record from the canal derived by literature – Bigelow, Schroeder (1948) reported a single juvenile (~110 cm TL, ♀, USNM 127134; Tab. **S3**) collected in 1937 at Miraflores Locks (Fig. 7). The canal includes several locks that account for sea level differences between Pacific and Caribbean waters (Fig. 7), and lift ships to Lake Gatun 26 m above sea level. Although increased observations of marine fish have been reported from Lake Gatun that successfully migrated through the locks (Colamarco *et al*., 2004; Smith *et al*., 2004; Sharpe *et al*., 2017; Schreiber *et al*., 2023), they do not include *C. leucas*. Neither historical reports on the fish of Lake Gatun (*e.g*., Herre, 1936; Hildebrand, 1939; Gunter, 1979) nor reports on the transfer of fish between ocean basins via the Panama Canal (McCosker, Dawson, 1975) mention *C. leucas*, suggesting its use is limited or absent, and *C. leucas* is an Isthmian relict in the eastern Pacific (Robertson *et al*., 2004).

The Panama Canal is, however, of interest concerning *C. leucas* conservation. The waterway presumably plays no role as a nursery in contrast to other low-salinity waterways discussed herein, because of its recent establishment and the apparent lack of sharks, but may affect *C. leucas* population structure in the western Atlantic and eastern Pacific. Populations are adapted to local-regional environmental conditions (Williams, 1966), which vary greatly between the eastern Pacific and Caribbean Sea. Testerman (2014) determined that the West Atlantic and Indo-Pacific populations of *C. leucas* are genetically distinct, but share some loci, which could be remnants of the gene pool prior to the emergence of the Isthmus of Panama, and/or admixture resultant from migration through the canal. These findings were supported by Postaire *et al*. (2024), with East

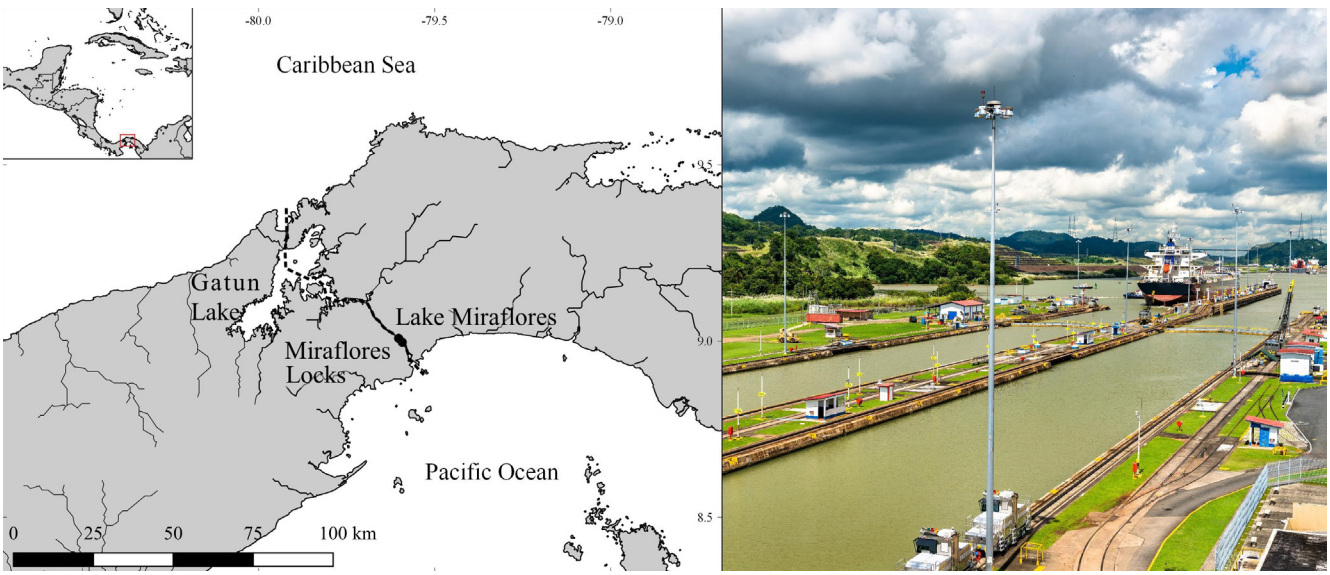

FIGURE 7 | The Panama Canal (dashed line) and Lake Gatun are of special scientific concern for *Carcharhinus leucas* in Central America. The only known record of this species from the canal zone derives from Miraflores Locks illustrated above (© Leonid Andronov).

Pacific *C. leucas* sampled in Panama (n = 15) genetically distinct from *C. leucas* in the Gulf of Mexico (n = 27), U.S. Atlantic coast (n = 7), and Brazil (n = 40). Considering these ocean basins have been largely biologically separated for millions of years, it is expected that *C. leucas* in the eastern Pacific are suited for different environmental conditions than those in the western Caribbean. The movement of sharks through the canal could thus have consequences if *C. leucas* are not suited to handle differences in temperature, salinity, and other factors, which could be transmitted to offspring. However, mingling between *C. leucas* populations originated in the Atlantic and Indo-Pacific by migrating specimens occasionally passing natural biogeographic barriers cannot be ruled out with certainty either (Daly *et al*., 2025).

Lake Maracaibo. Lake Maracaibo (Fig. 8) is the largest lake in South America, and has historically provided habiat to sharks as far south as the freshwaters of the Santa Ana River mouth (Schultz, 1949; Boeseman, 1964; Thorson, 1970b). The lake is connected to the Gulf of Venezuela and Caribbean Sea through the Maracaibo Strait, forming the largest estuary of northern South America (Cervigón *et al*., 1993; Plotnikov, Aladin, 2011). The lake and estuary are an important *C. leucas* nursery and parturition site based on the abundance of neonates and juveniles (92.8% of catch), and the presence of mature females (Tab. **S2**; Sánchez, Tavares, 2010; Tavares, Sánchez, 2012; Ehemann *et al*., 2019). However, Venezuela is a data-poor region, and little information exists on the occurrence, distribution, and habitat use of *Carcharhinus leucas* in its waters. *Carcharhinus leucas* is targetted by the Venezuelan fishing fleet, although fisheries data for this species is lacking (Yegres *et al*., 1996). Anonymous (2013) reported sporadic captures of *C. leucas* by fishers from Lake Maracaibo and the mouth of the Catatumbo River, though there is no freshwater fishery for this species.

Based on the largely outdated information and the paucity of reliable data for *C. leucas*, Lake Maracaibo did not manage to be designated as an Important Shark and Ray Area (ISRA). It is, however, an Area of Interest (AoI) but at least an Area of Interest (AoI) for South America by the ISRA project (Gausmann *et al*., 2025), indicating it had

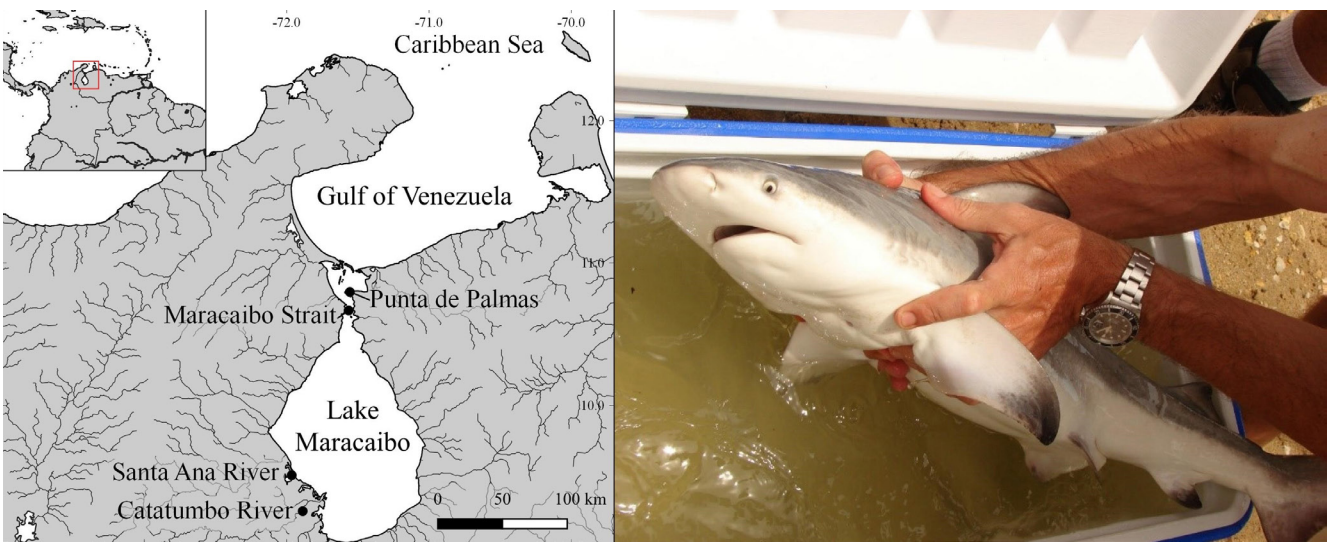

FIGURE 8 | Lake Maracaibo in South America provides habitat to small juvenile *Carcharhinus leucas*. Sharks with visible umbilical scars indicate that Lake Maracaibo is a nursery for bull sharks in the southern Caribbean Sea (© Rafael Tavares).

insufficient information to satisfy the ISRA criteria but may be designated as an ISRA in the future after a reassessment based on reliable data. This stresses the need for in-depth studies on *C. leucas* focusing on its distribution, abundance, and habitat use at this site.

Amazon River system. The Amazon River (Fig. 9) is the largest river system in the world, extending ~6,400 km through nine South American countries (Moura *et al*., 2016). Despite its geographic extent, records of *Carcharhinus leucas* from the Amazon are scarce (n = 35 over 110 years), and are mainly derived from incidental captures by artisanal fisheries. Starks (1913) first reported on a juvenile *C. leucas* (73.66 cm TL) from Belém, ~120 km from the sea, which has been followed by many authors since from Autazes, Iranduba, Lagoa dos Patos, Manaus, Santarém, and the Limoeiro, Mearim, Madeira, Tapajós, and Xingú, and Tocantins Rivers (Myers, 1952; Thorson, 1972b; Vizotto, Taddei, 1978; Werder, Alhanati, 1981; Soto, Nisa-Castro-Neto, 1998; Soto, Mincarone, 2004; Feitosa, Nunes, 2020; Gausmann, 2021; Tab. **S2**; Fig. 9). Myers (1952) reported on *C. leucas* in Iquitos, Peru ~4,000 km upstream, and Thorson (1972b) reported several *C. leucas* from the Ucayali River, Peru 4,200 km from the river mouth. This indicates that *C. leucas,* at least historically, made use of the entire Amazon main channel and beyond, spending years in this large river system (Dagosta, de Pinna, 2019).

The state of the Amazon, however, is at risk. Several hydropower plants and dams have been proposed, which pose a serious threat to this biodiversity hotspot that includes 2.406 native freshwater fish species, many of which are endemic (Jézéquel *et al*., 2020; Pelicice *et al*., 2021). The exploitation of fish in the Amazonian region has also increased at alarming levels (Wosnick *et al*., 2019). Because it is only sporadically caught, *C. leucas* is not of commercial interest in the Amazon, but Ferreira *et al*. (1996) reported they are occasionally found in fish markets of Santarém ~700 km from the sea where they are not utilized as food, rather displayed as tourist attractions (Fig. 9). The mouth and the estuary of the Amazon have been outlined as an important global elasmobranch conservation hotspot (Lutz *et al*., 2024), thus strong fishing pressure along

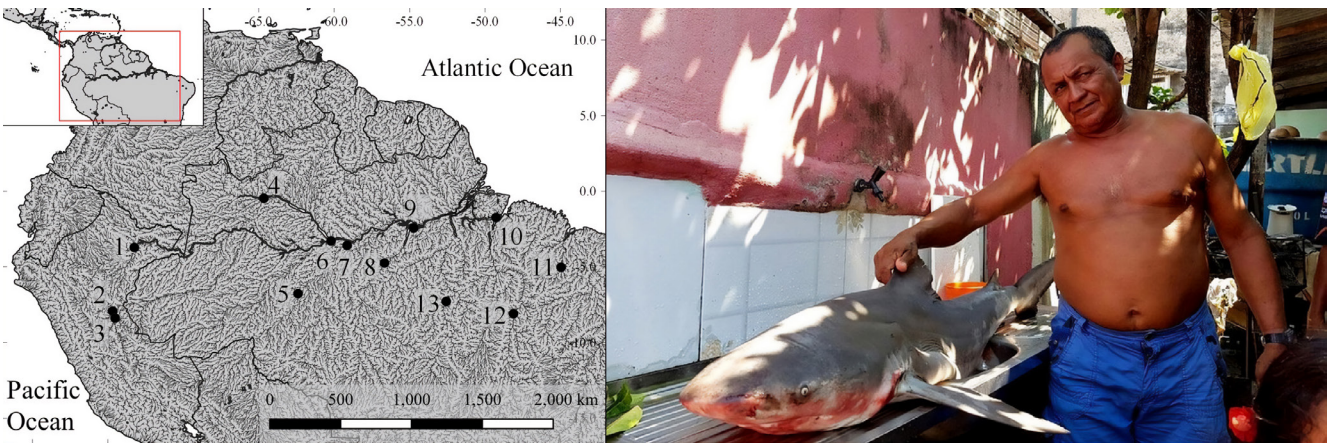

FIGURE 9 | The Amazon River system crosses multiple countries in South America, including Brazil where this fisherman poses with an immature male *Carcharhinus leucas* (~150 cm TL) incidentally captured in fishing nets on the 29th November 2016 along the river at Pinduri (Santarém, Pará State, Brazil) (© Jeso Carneiro). 1) Iquitos, 2) Ucayali River, 3) Pucallpa, 4) Negro/Salimoes River, 5) Madeira River, 6) Iranduba, 7) Autazes, 8) Tapajos River, 9) Pinduri, Santarem, 10) Limoeiro River, 11) Mearim River, 12) Tocantins River, 13) Xingu River.

the Amazon mouth expectantly affects the reproductive output of *C. leucas* considering the importance of this region for neonate, juvenile, and pregnant *C. leucas* (Wosnick *et al*., 2024).

Recommendations. Survey results from scientists and the literature review revealed commonalities in research and conservation priorities for *Carcharhinus leucas* in Latin America:

1. Assess and mitigate fisheries impacts (targeted and bycatch).
2. Engage communities and governments to ensure sustainable, non-destructive fisheries, and eliminate other threats (*e.g*., habitat degradation, pollution).
3. Conduct stock assessments that describe shark densities, age structure, distribution, essential habitat (*e.g*., nurseries), and genetic structure.
4. Identify and investigate previously unknown nurseries / re-assess historic nurseries.
5. Understand regional/local biological characteristics of *C. leucas*.
6. Secure/allocate resources for research efforts.

Data gaps create barriers to conservation efforts, and the paucity of recent information on *C. leucas* in Latin America makes this a priority worth addressing because of the species' ecological role in freshwater, brackish, and marine ecosystems and its cultural importance in some countries (Astorqui, 1967; Thorson, 1982; Peréz, Mondragón, 2011). There are historic records of *C. leucas* in > 90 low-salinity habitats across Latin America (Gausmann, 2021), and recent media reports confirm its presence in some of these locations (Tab. **S2**). However, the infrequency of these reports highlights conservation concerns. Like many other sharks, *C. leucas* was significantly overfished in Latin America in the 20th century (*e.g*., Thorson, 1982; Saldaña-Ruiz *et al*., 2017), and overfishing is still the most persistent threat sharks face today (Dulvy *et al*., 2021; Fogliarini *et al*., 2024). Despite management efforts, recent densities estimates of *C. leucas* in Latin America indicate that i) fishery management policies were implemented too late and/or ignored, and ii) recovery may occur on timescales beyond human generation times due to the low reproductive rate of this species (Smith *et al*., 1998; Saldaña-Ruiz *et al*., 2022), particularly if overfishing is permitted to occur unchecked for extended periods as they were in the 20th century. While surveys and literature were not reviewed across the entire geographic range of *C. leucas* in Latin America, the locations discussed are representative of many other parts of this region where *C. leucas* is understudied (*e.g*., Usumacinta River, Mexico; Patuca River, Honduras; Chepo River, Panama; Magdalena River, Colombia; Orinoco River; Venezuela). Research, management, and conservation approaches, along with historic and current knowledge of *C. leucas* and the threats to this species, are not homogenous. However, there are some nearly ubiquitous concerns and solutions to address the understudied nature of *C. leucas* in Latin America, which we summarize below. As it was in the 20th century, research on *C. leucas* must become a priority again if this species is to recover and be preserved in Latin America.

Fisheries and other human uses. Unsustainable fishing has been and is the main threat to *C. leucas* in Latin America (Bonfil, 1997, 2014; Saldaña-Ruiz *et al*., 2017, 2022; Martínez-Candelas *et al*., 2020). In many parts of the world, including Latin America, fishing activities overlap with essential *C. leucas* habitats, which affects population stability and recovery (Osuka *et al*., 2025). In response to fisheries management, but more likely a lack of sharks, *C. leucas* are no longer reported as target species in freshwater systems of Latin America (Rojas *et al*., 2000; Bustamante, Lamilla, 2006). However, they are still taken as bycatch (Pérez-Jimenez, Mendez-Loaeza, 2015), and harvest rates are largely undocumented, because of the geographic separation between fishers and managers, and the limited resources allocated to fisheries management. If essential *C. leucas* habitats can be identified (see Distributions and Movements below), managing these waters more strictly could be a solution, but stakeholder engagement will be needed (*e.g*., Sabbagh, Hickey, 2019; Williams *et al*., 2023).

It is unlikely resources allocated to fisheries enforcement will be adequate due to economic conditions in many Latin American countries. Thus, compliance and self-enforcement are essential for *C. leucas* recovery. Working with fishers collaboratively to develop management plans will be necessary to achieve this goal, since stakeholders are more compliant when they are included in management decisions (Shiffman *et al*., 2021). Workshops with fishers in communities that overlap with essential *C. leucas* habitat offer an opportunity to give stakeholders a voice in decision-making, and in turn ownership in complying with fisheries regulations and supporting conservation goals (*e.g*., Sabbagh, Hickey, 2019; Dinkel, Sánchez-Lizaso, 2020). A co-management approach will aid in compliance and fisheries-dependent monitoring (Morgan, Burgess, 2005), which will be more effective for monitoring *C. leucas* than relying on fisheries-independent sampling alone (see Stock Assessments and Biological Characteristics below), and help develop ventures for alternative sources of income generated from sharks tied to their conservation rather than their harvesting.

Sharks are extensively harvested for their fins and meat around the world, but the perspective that sharks are more valuable alive than dead has taken hold in some countries (Cisneros-Montemayor *et al*., 2020). For example, The Bahamas declared its waters a shark sanctuary in 2011, and sharks cannot be targeted or landed in order to support tourism (Sherman *et al*., 2018). Shark diving generates more than $140 million US annually in The Bahamas, and ecotourism offers a viable alternative to fisheries for *C. leucas* in some parts of Latin America. Sánchez Crispín *et al*. (2008) described the sharks of Lake Nicaragua as a tourist attraction when they were abundant. Suárez (2016) also reported the value of Lake Nicaragua's aquatic resources, and outlined the potential economic benefits of *C. leucas* in generating income through tourism. Fishers in many developing countries have turned to ecotourism, because it offers a more profitable and reliable livelihood than fishing, thus economic benefits resultant from keeping *C. leucas* alive is expected in many Latin American countries. Logistics (*e.g*., marketing, scheduling) and initial financial support will, however, be needed for this transition to be successful, and ecotourism is not only tied to protecting sharks, but their habitat.

Waterway alterations. Considering the lack of recent information on *C. leucas* in much of Latin America, conservative decision making via the precautionary approach is warranted for fisheries regulations, and more holisticly, regulating human degradation

of ecosystems. Recent adoptions of ecosystem-based management, *i.e.*, an approach that recognizes the full array of interactions within an ecosystem, are likely too multidimensional for most Latin American countries due to resource limitations (*e.g.*, Dulvy *et al.*, 2017; Mouton *et al.*, 2025). Yet, habitat protection is within the capacity of most countries, with special consideration given to the alteration of waterways, which is among the most destructive forms of habitat degradation that pose a threat to *C. leucas* and many other species in Latin America (Rigby *et al.*, 2021).

Hydropower plants along rivers prevent the dispersal of fish, and have led to widespread declines in abundance and biodiversity (Rolls *et al.*, 2014; Parreira, Nabout, 2023). For example, dams now extensively limit the migrations of *C. leucas* in the Zambezi River from 1,120 km historically to ~640 km (Bass *et al.*, 1973; Bell-Cross, Minshull, 1988; Gausmann, 2021). In North America's Mississippi River, dams now prevent *C. leucas* from migrating to the upper reaches of the river where it was historically reported (Thomerson *et al.*, 1977), with similar consequences in other American rivers (*e.g.*, Matich *et al.*, 2020a). In Iraq, *C. leucas* once traveled up the Tigris River to Baghdad ~850 km from the sea, but today dams prevent their movements upstream (Moore, 2018; Gausmann, 2021). In Latin America, the Bayano River in Panama was presumably a historic nursery for the east Pacific population of *C. leucas*, however, it is no longer accessible for parturition because of the damming of the river (Montoya, Thorson, 1982). Hydropower dams in the Tocantins-Araguaia River basin and other parts of Amazonia similarly threaten *C. leucas* (Feitosa, Nunes, 2020). The consequences of hydroelectric dams on *C. leucas* in Latin America are understudied, but it is suspected that current distributions are more restricted because of impassable structures in many waterways, and continued river fragmentation will affect both the quality and quantity of potential nursery habitats, and therefore conservation efforts. As such, the prevention of future dam construction is an important conservation measure across Latin America, and understanding the distribution and movement patterns of *C. leucas* is an important research priority to assess and mitigate these impacts.

Distributions and movements. *Carcharhinus leucas* exhibit notable ontogenetic habitat shifts, spending years in low-salinity environments as juveniles, then transitioning to marine waters (Werry *et al.*, 2011). Females seek out these low-salinity habitats for parturition, and regional philopatry can lead to long distance migrations to and from nurseries by adult females (Daly *et al.*, 2014; Heupel *et al.*, 2015; Lea *et al.*, 2015; Niella *et al.*, 2017; Smoothey *et al.*, 2019; Lédée *et al.*, 2021; Lubitz *et al.*, 2022). Evolutionarily, this behavior is hypothesized to optimize fitness by increasing offspring survival, because the habitation of low-salinity nursery habitats limits interactions with marine predators, thereby reducing risk (Heupel, Simpfendorfer, 2011; Matich, Heithaus, 2015; Lofthus *et al.*, 2024). Historically, many Latin American estuaries and river systems functioned as nurseries, but today, the locations of *C. leucas* nurseries are unclear across much of the region. For example, Hoyos-Padilla *et al.* (2023) recently reported on pregnant female bull sharks at Playa del Carmen, Quintana Roo, Mexico, but it is unclear where their parturition grounds are located. The nearest known nursery is in Chetumal Bay ~360 km south of Playa del Carmen (Blanco-Parra *et al.*, 2022), but there may be more proximate potential nurseries that have not yet been identified. Lake Nicaragua and Lake Izabal were historically nurseries (Thorson *et al.*, 1966; Jensen, 1976), but

the abundance and distribution of *C. leucas* in these systems has not been studied for decades, thus their function is unclear (Heupel *et al*., 2007). Therefore, the ability to protect and regulate fisheries in essential nursery grounds is hindered (*e.g*., bans on destructive methods like gillnets; Froeschke *et al*., 2013). Understanding the connection between adult females and low-salinity habitats as parturition sites is a necessary step to address this knowledge gap, and many surveyed experts highlighted the need for investigating *C. leucas* distributions and movements, along with nursery locations. The use of telemetry (satellite, acoustic) offers the opportunity to collect meaningful data to accomplish this goal, particularly pop-up satellite archival tags (PSATs) that only require a single tagging event. Yet, considering the limited resources currently available for shark research in Latin America and the cost of employing these methods, other approaches may be more advantageous, with telemetry providing complementary data when affordable. Catch records and sample collection from fisheries landings offers a more widely applicable starting point for data collection (Saldaña-Ruiz *et al*., 2017; Gibson *et al*., 2019) that can subsequently be used for more targeted scientific inquiry. Our survey results revealed that many Latin American shark scientists depend on fisheries data because of the paucity of financial support for research. Considering fisheries data is familiar to scientists in the region, governments should strive to make this data more widely accessible, and increase the ability of fishers to report their landings.

Stock assessment and biological characteristics. Adult *C. leucas* are found throughout the coastal waters of Latin America, and select locations (*e.g*., Terminos Lagoon) are viable nurseries based on the abundance and residency of juvenile *C. leucas* (Uribe, 1993; Bonfil, 1997). Yet, stock assessments and evaluations of regional biological characteristics (*e.g*., age-growth) of *C. leucas* in marine and freshwater ecosystems of Latin America are needed. Considering the limited financial resources available for such endeavors, and limited reporting infrastructure for many Latin American fisheries (although see suggestion above), the use of media reports is a viable starting point (*e.g*., Burgess *et al*., 2010). The examination of media reports for records of *C. leucas* has a long history (*e.g*., Kennedy, 1937; Thomerson *et al*., 1977; Coad, Al-Hassan, 1989; Matich *et al*., 2020a; Shell, Gardner, 2021), and while reports of *C. leucas* sightings and incidental catches by fishers (Tab. **S2**) are of limited scientific value on their own, they offer researchers locations where sharks may be sampled with success, and can be a starting point for designing and implementing more formal assessments. The use of fishers' local ecological knowledge has recently increased not only in shark sciences, including studies of *C. leucas* (*e.g*., Nascimento *et al*., 2023), but teleost fish in Latin America (*e.g*., Silvano *et al*., 2023), and sawfish from the San Juan River in Costa Rica and Nicaragua (Astorga, 2023). Working with communities that encounter *C. leucas* is thus an important priority to not only reduce their impacts (see Fisheries and other Human Uses above), but provide accounts that will increase the efficacy of scientific inquiry (Gibson *et al*., 2019; Sun *et al*., 2021).

Working with local communities will require several key components. First, residents must be encouraged, if not incentivized, to report all shark sightings and captures with photographic evidence when possible, including sharks that are harvested for consumption and sale. While the reduction/elimination of fishing for *C. leucas* in Latin America is a priority, developing trust with local stakeholders is currently a more pressing conservation

goal. Communities must then be empowered to share reports of *C. leucas* encounters, either i) online with searchable keywords (*e.g.*, bull shark, river shark, freshwater shark) and pertinent information (location, date of sighting/capture, approximate size), or ii) with a trusted conservationist or research scientist. Iqbal *et al*. (2019a,b) and Gausmann, Hasan (2022) investigated the distribution of *C. leucas* in fresh waters of Indonesia by captures from fishers. Feitosa *et al*. (2016) and Feitosa, Nunes (2020) similarly worked with local fishers in Brazil, and data on the occurrence of *C. leucas* reported by fishers in the Patuca River, Honduras, was published by Esselman, Opperman (2010). The acquisition of local ecological knowledge will require relationships between scientists and community liaisons who can bridge language and cultural gaps, and incentives may be necessary, which could take on many forms, including economic benefits. Data will need to be centralized in a location accessible to conservation organizations, management agencies, researchers, and the public comparable to the International Shark Attack File – ISAF (https://www.floridamuseum.ufl.edu/shark-attacks/). Future advancements in artificial intelligence (AI) also offer the opportunity to broadly search online records and report findings to the centralized database. More formal stock assessments and studies on *C. leucas* biology can then be designed and implemented strategically to optimize data collected in lieu of resource limitations.

Visiting fish markets and interacting with fishmongers offers another avenue from which to gather information and collect specimens (Moore, 2018), which can aid stock assessments that rely on the evaluation of genetic relatedness among individuals within and across management areas. The Gulf of Mexico and Caribbean Sea includes dozens of Exclusive Economic Zones (EEZs), and the Tropical Eastern Pacific is comprised of 10 countries alone. Defining bull shark stocks in Latin America is thus of great consequence, because the management strategies implemented by one country may impact shark conservation in others (*e.g.*, Godin, Worm, 2010), and it may help identify potential nurseries that disproportionately contribute to the population(s). Therefore, understanding the genetic structure of Latin American bull sharks is a priority. Laurrabaquio-Alvarado *et al*. (2021) recently reported on a divergent lineage of *C. leucas* in the Caribbean Sea, reflecting a phylogeographic break from adjacent populations in the Gulf of Mexico and South America. The Caribbean Sea was presumably supported historically by *C. leucas* from the Lake Nicaragua-San Juan River and Lake Izabal-Dulce River nurseries, but this is expected to have changed in recent decades because of their near extirpation. Blanco-Parra *et al*. (2022) recently identified Mexico's Chetumal Bay as another important nursery area for the Caribbean lineage of *C. leucas*. However, the genetic structure of *C. leucas* in Latin America is still largely unresolved, hindering our ability to understand how effective conservation or overfishing in one nursery could impact *C. leucas* in others.

Bull sharks are highly mobile, with large geographic ranges. We therefore do not expect sharks in disparate Caribbean and Gulf of Mexico nurseries to be unique populations/stocks, but there may be genetic structuring based on the proximity of nurseries (TinHan *et al*., 2020). *Carcharhinus leucas* exhibits regional philopatry, with females exhibiting site fidelity for reproductive purposes (Tillett *et al*., 2012; Laurrabaquio-Alvarado *et al*., 2019). This behavior can limit genetic exchange between populations with site-attachments (Pirog *et al*., 2019; Glaus *et al*., 2020; Devloo-Delva *et al*., 2023), and increases susceptibility to overexploitation, because overfishing

a freshwater nursery could significantly impact population stability. Management differences across Latin American countries, including the prevention *vs*. allowance of overfishing, may consequently lead to some freshwater systems serving as *C. leucas* sources and others as sinks. Environmental and ecological conditions shape population dynamics, but recent human actions have likely altered source-sink dynamics, and potentially affected the contributions bull sharks from each nursery make toward the gene pool. As such, assessments of genetic relatedness in freshwater systems, and across Latin America more broadly, is paramount to *C. leucas* conservation efforts in the region. Collecting shark samples from fish markets has been a widely implemented practice (*e.g*., Peiris *et al*., 2021), and should be used to complement more traditional approaches to increase sample sizes. Such an endeavor can be resource intensive, therefore establishing relationships with communities who regularly encounter sharks offers a valuable pathway to achieving this goal (see above).

Climate change and future perspectives. Finally, while overfishing and habitat degradation are the most pressing issues facing elasmobranchs today (Dulvy *et al*., 2021), climate change poses an additional threat. As water temperatures rise, aquatic animals in tropical latitudes face the challenge of persisting in warmer, less oxygenated waters, or shifting their distributional ranges to higher latitudes (Perry *et al*., 2005; Dahms, Killen, 2023). While behavioral adjustments have been observed among some shark species (*e.g*., Hammerschlag *et al*., 2022; Bowers, Kajiura, 2023), the effects of climate change on this taxonomic group is vastly understudied. Among *C. leucas*, coastal ecosystems in temperate and subtropical latitudes may become more suitable for juveniles, as has been observed in the northwestern Atlantic Ocean (Bangley *et al*., 2018; Matich *et al*., 2024; Mullins *et al*., 2024). However, the impacts in more equatorial nursery habitats, including those in Latin America, have not been evaluated (*e.g*., Cerutti-Pereyra *et al*., 2024). Coupled with challenges pertaining to historic overfishing and nursery degradation, there is a need to address data gaps concerning *C. leucas* biology and ecology across the region to determine how *C. leucas* will respond to climate change (Matich *et al*., 2024).

Domestic funding is currently very limited for elasmobranch research in much of Latin America. Comparatively, financial support is much greater in developed countries because of the beneficial subsidies (*e.g*., fisheries management) that governments and management organizations invest in to preserve their natural resources. Collaborations between shark scientists in developed countries that have greater access to financial resources, with those in developing countries that have access to species of conservation interest (*i.e*., *C. leucas*) is a desirable mechanism to accomplish the research and conservation objectives we propose. If the protection and recovery of historically overfished species like *C. leucas* is a priority in the region, local governments and NGOs must offer more support to Latin American scientists, and collaboration and support from international partners is necessary. As such, we encourage scientists to intensify investigations on *C. leucas* distribution, habitat use, and population status to mitigate current data gaps necessary for conservation decisions, with a focus on updating the status of locations in Latin America that have been historically identified as crucial for *C. leucas* but are now understudied and largely unprotected. This has the potential to contribute to the long-term survival of this iconic predator, which is indispensable for the stability of freshwater, brackish, and marine ecosystems in the region.

ACKNOWLEDGMENTS

We are very grateful to all the scientists across Latin America who responded to our survey request and contributed to this research. We thank Grettel Marisol Hernández-Fernández (UNAN) for providing information on elasmobranchs in Nicaragua, and Lennart Schreiber (UB, ZMT) for sharing information on investigation methods used in the Panama Canal. We also give thanks to Diana Lon (ECOSUR) for information on the distribution of *C. leucas* in Terminos Lagoon. We acknowledge the collection manager Diane Pitassy (SI) for the production and transmission of photographic material of a voucher specimen housed in the ichthyological collection of the Smithsonian Institution. We are grateful to Andrés Irigoyen-Solis (Ciencia de Tiburones, Mexico.) for a picture of *C. leucas* from Campeche, Rodrigo Barreto (ICMBio) for a picture from a fish market in Northeast Brazil, Jeso Carneiro (Santarém, Amazônia) for his permission to publish a photo of *C. leucas* from the Amazon River, and Rafael Tavares (CIT, IVIC) for a photo of *C. leucas* from Lake Maracaibo. We are grateful to the following persons for providing hard-to-access literature: Eloisa Pinheiro Giareta (UFPR), Mariana Haueisen Pinheiro (PUCRS), Nicolás R. Ehemann (Universität Konstanz), Adrián Felipe González-Acosta (IPN), Felipe Galván-Magaña (IPN), Alexandre Pires Marceniuk (UFPB), and Edgar Mauricio Hoyos-Padilla (Pelagios Kakunjá). We also acknowledge the editors and anonymous reviewers of Neotropical Ichthyology.

REFERENCES

- **Alencar CAG, Santana JVM, Oliveira GG.** Descrição da pesca de tubarões com espinhel de fundo na região norte do Brasil, durante 1996 e 1997. Arq Cienc Mar. 2001; 34(1-2):143-49. Available from: https://labomar.ufc.br/wp-content/uploads/2017/01/acm-2001-34-17.pdf
- **Alvarado LCP, Álvarez MR, Mojica A, Dix M, Dix M.** La ictiofauna del Refugio de Vida Silvestre Bocas del Polochic y la cuenca del lago de Izabal: composición, distribución y ecología. Guatemala City: Organización de las para la Educación, la Ciencia y la Cultura, Universidad del Valle de Guatemala; 2005.
- **Álvarez TA, Jiménez JCP, Pool DGP, Hueter R.** Spatiotemporal catch trends and biological fishery indicators of the bull shark, *Carcharhinus leucas*, in the Mexican Atlantic. Proc Gulf Caribb Fish Inst. 2020; 73:6–07. Available from: https://proceedings.gcfi.org/wp-content/uploads/2023/04/73-GCFI-PDF-3.pdf
- **Angulo A, Betts JT, González-Alemán NJ, Castañeda E, van den Berghe E, Elías DJ *et al*.** Continental fishes of Nicaragua: diversity, distribution and conservation status; with an annotated and illustrated checklist of species and an identification guide to families. Zootaxa. 2023; 5376(1):1–89. https://doi.org/10.11646/zootaxa.5376.1.1
- **Ministerio del Poder Popular para la Agricultura y Tierras.** Plan de acción national para el aprovechamiento sustentable de tiburones en Venezuela. Caracas: Ministerio del Poder Popular para la Agricultura y Tierras Instituto Socialista de la Pesca y Acuicultura Gerencia de Ordenación Pesquera; 2013. Available from: http://www.fao.org/3/a-br385s.pdf
- **Applegate SP, Soltelo-Macias F, Espinosa-Arrubarrena L.** An overview of Mexican shark fisheries, with suggestions for shark conservation in Mexico. In: Branstetter S, editor. Conservation biology of elasmobranchs. NOAA Technical Report NMFS 115. Washington, DC: National Oceanic and Atmospheric Adminitration; 1993. p.31-38. Available from: https://repository.library.noaa.gov/view/

noaa/6120/noaa_6120_DS1.pdf

- **Asiedu B, Amponsah SK, Peirre F, Apraku A, Henneh S, Ntim L *et al*.** A closer look at socio-economic and management perspectives of shark fishery in Ghana. J Wildl Biodivers. 2024; 8(1):366–85. https://doi.org/10.5281/zenodo.10206993
- **Astorga L.** Costa Rica y Nicaragua comparten potencial para salvar al pez sierra en extinción [Internet]. San José: Consejo Nacional para Investigaciones Científicas y Tecnológicas (CONICIT); 2023. Available from: http://www.conicit.go.cr/prensa/historico/historico_noticias/Pez_sierra.aspx
- **Astorqui I.** Investigaciones de un Jesuita en aguas de Nicaragua. 4. Nuestro tiburon. Rev Conservadora. 1967; 79(4):69–71. Available from: https://sajurin.enriquebolanos.org/docs/887.pdf
- **Astorqui I.** Peces de la cuenca de los grandes lagos de Nicaragua. Managua: Publicaciones Nicaragüenses; 1974.
- **Bangley CW, Paramore L, Shiffman DS, Rulifson RA.** Increased abundance and nursery habitat use of the bull shark (*Carcharhinus leucas*) in response to a changing environment in a warm-temperate estuary. Sci Rep. 2018; 8(1):6018. https://doi.org/10.1038/s41598-018-24510-z
- **Barthem RB.** Development of commercial fisheries in the Amazon Basin and consequences for fish stocks and subsistence fishing. In: Clüsener-Godt M, Sachs I, editors. Brazilian perspectives on sustainable development of the Amazon region. Man and the Biosphere Series 15. Paris: UNESCO; 2015. p.175–204.
- **Bass AJ, D'Aubrey JD, Kistnasamy N.** Sharks of the east coast of Southern Africa. Vol. I. The genus *Carcharhinus* (Carcharhinidae). Invest Rep Oceanogr Res Inst. 1973; 33:1–168.
- **Becerril-García EE, Arauz R, Arellano-Martínez M, Bonfil R, Ayala-Bocos A, Castillo-Géniz JL *et al*.** Research priorities for the conservation of chondrichthyans in Latin America. Biol Conserv. 2022; 269:109535. https://doi.org/10.1016/j.biocon.2022.109535
- **Bell-Cross G, Minshull JL.** The fishes of Zimbabwe. Harare: National Museums and Monuments of Zimbabwe; 1988.
- **Bigelow HB, Schroeder WC.** Sharks. In: Fishes of the western North Atlantic. Mem Sears Found Mar Res. New Haven: Yale University; 1948. p.59–576. https://doi.org/10.5962/bhl.title.7464
- **Bizzarro JJ, Smith WD, Castillo-Géniz JL, Ocampo-Torres A, Márquez-Farías JF, Hueter RE.** The seasonal importance of small coastal sharks and rays in the artisanal elasmobranch fishery of Sinaloa, Mexico. Pan-Am J Aquat Sci. 2009; 4(4):513–31. Available from: https://panamjas.org/pdf_artigos/PANAMJAS_4(4)_513-531.pdf
- **Blaber SJM, Barletta M.** A review of estuarine fish research in South America: what has been achieved and what is the future for sustainability and conservation? J Fish Biol. 2016; 89(1):537–68. https://doi.org/10.1111/jfb.12875
- **Blanco-Parra MDP, Laurrabaquio-Alvarado NS, Díaz-Jaimes P, Niño-Torres CA.** Evidence of a nursery area for bull shark, *Carcharhinus leucas* (Müller y Henle, 1839) in the Mesoamerican Reef System region. Environ Biol Fish. 2022; 105(9):1193–202. https://doi.org/10.1007/s10641-022-01338-1
- **Boeseman M.** Notes on the fishes of western New Guinea III. The fresh water shark of Jamoer lake. Zool Meded. 1964; 40(3):9–22. Available from: https://repository.naturalis.nl/pub/318979
- **Bonfil R.** Overview of world elasmobranch fisheries. FAO Fisheries Technical Paper No. 341. Rome: FAO; 1994. Available from: https://www.fao.org/3/v3210e/V3210E00.htm
- **Bonfil R.** Status of shark resources in the Southern Gulf of Mexico and Caribbean: implications for management. Fish Res. 1997; 29(2):101–17. https://doi.org/10.1016/S0165-7836(96)00536-X
- **Bonfil, R.** Diagnóstico del estado de conservación de los elasmobranquios en México. Informe final de consultoría a conanp. México, D.F.: CONANP; 2014.
- **Bowers ME, Kajiura SM.** A critical evaluation of adult blacktip shark, *Carcharhinus limbatus*, distribution off the United States East Coast. Environ Biol Fishes. 2023; 106(8):1797–813. https://doi.org/10.1007/s10641-023-01449-3

- **Branstetter S, Stiles R.** Age and growth estimates of the bull shark, *Carcharhinus leucas*, from the northern Gulf of Mexico. Environ Biol Fishes. 1987; 20(3):169-81. https://doi.org/10.1007/BF00004952
- **Brinson MM.** The organic matter budget and energy flow of a tropical lowland aquatic ecosystem. [PhD Dissertation]. Gainesville: University of Florida; 1973. Available from: https://doi.org/10.5962/bhl.title.16504
- **Brinson MM, Nordlie FG.** II. Lakes. 8. Central and South America: Lake Izabal, Guatemala. Verh Int Ver Theor Angew Limnol. 1975; 19(2):1468–79. https://doi.org/10.1080/03680770.1974.11896206
- **Burgess GH, Fernandez de Carvalho J, Imhoff JL.** An evaluation of the status of the largetooth sawfish, *Pristis perotteti*, based on historic and recent distribution and qualitative observations of abundance. Gainesville, Florida: Florida Museum of Natural History; 2010. Available from: https://www.floridamuseum.ufl.edu/wp-content/uploads/sites/80/2017/05/ltsawfish_finalreport_2010.pdf
- **Burke JD.** The fresh-water shark in Nicaragua. Natl Geogr Soc Res Rep. 1979; 1970:53-63.
- **Bustamante C, Lamilla J.** Realidades en la pesquería de tiburones de la Costa del Pacífico Latinoamericano. Apéndices y Memorias. Valdivia: Universidad Austral de Chile; 2006.
- **Cailliet GM, Musick JA, Simpfendorfer CA, Stevens JD.** Chapter 3: Ecology and life history characteristics of chondrichthyan fish. In: Fowler SL, Cavanagh RD, Camhi M, Burgess GH, Cailliet GM, Fordham SV *et al*., editors. Sharks, rays and chimaeras: the status of the chondrichthyan fishes. Gland, Cambridge: IUCN/SSC Shark Specialist Group & IUCN; 2005. p.12–18. Available from: https://portals.iucn.org/library/efiles/documents/2005-029.pdf
- **Campos Flores GJ, Crespo Guerrero JM.** Organización espacial de la pesca comercial ribereña en el área de protección de flora y fauna Laguna de Términos, México. Investig Geogr. 2018; 96:1–21. https://doi.org/10.14350/rig.59558
- **Castillo-Géniz JL, Márquez-Farias JF, De La Cruz MR, Cortés E, Del Prado AC.** The Mexican artisanal shark fishery in the Gulf of Mexico: towards a regulated fishery. Mar Freshw Res. 1998; 49(7):611–20. https://doi.org/10.1071/MF97120
- **Castro G.** Tiburones rodean la isla de Ciudad del Carmen, Campeche [Internet]. Mérida, Yucatán, Mexico: Publicidad Poresto; 2022. Available from: https://www.poresto.net/campeche/2022/12/2/tiburones-rodean-la-isla-de-ciudad-del-carmen-campeche-361901.html
- **Castro-Aguirre JL.** Catálogo sistemático de los peces marinos que penetran a las aguas continentales de México con aspectos zoogeográficos y ecológicos. Inst Nl Pesc, Ser Cient. 1978; 19:1–298. Available from: https://www.inapesca.gob.mx/portal/Publicaciones/Series/1970s-Serie-Cientifica/SC-19-CastroAguirre-1978-Catalogo-peces-marinos.pdf?download
- **Castro-Aguirre JL, Espinosa Pérez H, Schmitter-Soto JJ.** Ictiofauna estuarino-lagunar y vicaria de México. México, D.F.: Editorial Limusa; 1999.
- **Cerutti-Pereyra F, Drenkard EJ, Espinoza M, Finucci B, Galván-Magaña F, Hacohen-Domené A *et al*.** Vulnerability of Eastern Tropical Pacific chondrichthyan fish to climate change. Glob Change Biol. 2024; 30(7):e17373. https://doi.org/10.1111/gcb.17373
- **Cervigón F, Cipriani R, Fischer W, Garibaldi L, Hendrickx M, Lemus AJ *et al*.** Field guide to the commercial marine and brackish-water resources of the northern coast of South America. Rome: FAO; 1993.
- **Cisneros-Montemayor AM, Becerril-García EE, Berdeja-Zavala O, Ayala-Bocos A.** Shark ecotourism in Mexico: Scientific research, conservation, and contribution to a Blue Economy. In: Lowry D, Larson SE, editors. Advances in Marine Biology 85(1). Sharks in Mexico: Research and Conservation Part B. London: Academic Press; 2020. p.71–92. https://doi.org/10.1016/bs.amb.2019.08.003
- **Coad BW, Al-Hassan LAJ.** Freshwater shark attacks at Basrah, Iraq. Zool Midd East. 1989; 3(1):49–54. https://doi.org/10.1080/09397140.1989.10637574
- **Coates AG, Stallard RF.** How old is the isthmus of Panama? Bull Mar Sci. 2013; 89(4):801–13. https://doi.org/10.5343/bms.2012.1076
- **Colamarco AAA, García J, Rivera R, Núñez M.** Colecta y análisis de muerstras biológicas de los Lagos Gatún y Miraflores: No. 5: Ictiofauna. Panamá: Universidad de Panamá; 2004.

- **Compagno LJV.** FAO Species Catalogue. Vol. 4. Sharks of the World. An annotated and illustrated catalogue of shark species known to date. FAO Fish Synop. 1984; 125(2):251-655. Available from: https://www.fao.org/4/ad123e/ad123e00.htm
- **Constance JM, Garcia EA, Pillans RD, Udyawer V, Kyne PM.** A review of the life history and ecology of euryhaline and estuarine sharks and rays. Rev Fish Biol Fisheries. 2024; 34:65–89. https://doi.org/10.1007/s11160-023-09807-1
- **Contreras-MacBeath T, Pérez BJR, Mejia-Mojica H, Rivas-González JM.** Fishes of Cocibolca, the great Central American lake. J Threat Taxa. 2024; 16(1):24589–96. https://doi.org/10.11609/jott.8506.16.1.24589-24596
- **Cruz-Martínez A, Chiappa-Carrara X, Arenus-Fuentes V.** Age and growth of the bull shark, *Carcharhinus leucas*, from southern Gulf of Mexico. J Northw Atl Fish Sci. 2005; 35:367–74. https://doi.org/10.2960/J.v35.m481
- **Curtis TH, Adams DH, Burgess GH.** Seasonal distribution and habitat associations of bull sharks in the Indian River lagoon, Florida: a 30-year synthesis. Trans Am Fish Soc. 2011; 140(5):1213-26. https://doi.org/10.1080/00028487.2011.618352
- **Curtis TH, Parkyn DC, Burgess GH.** Use of human-altered habitats by bull sharks in a Florida nursery area. Mar Coast Fish. 2013; 5(5):28-38. https://doi.org/10.1080/19425120.2012.756438
- **Dagosta FCP, de Pinna M.** The fishes of the Amazon: distribution and biogeographical patterns, with a comprehensive list of species. Bull Am Mus Nat Hist. 2019; 431:1–163. https://doi.org/10.1206/0003-0090.431.1.1
- **Dahms C, Killen SS.** Temperature change effects on marine fish range shifts: A meta-analysis of ecological and methodological predictors. Glob Change Biol. 2023; 29(16):4459–79. https://doi.org/10.1111/gcb.16770
- **Daly R, Smale MJ, Cowley PD, Froneman PW.** Residency patterns and migration dynamics of adult bull sharks (*Carcharhinus leucas*) on the east coast of Southern Africa. PLoS ONE. 2014; 9(10):e109357. https://doi.org/10.1371/journal.pone.0109357
- **Daly R, Murray TS, Roberts MJ, Schoeman DS, Lubitz N, Barnett A *et al*.** Breaking barriers: Transoceanic movement by a bull shark. Ecology. 2025; 106(5):e70096. https://doi.org/10.1002/ecy.70096
- **Davies WD, Pierce PC.** Lake Nicaragua Fisheries Survey. Auburn & Washington, D.C.: International Center for Aquaculture & Agency for International Development; 1972.
- **Devloo-Delva F, Burridge CP, Kyne PM, Brunnschweiler JM, Chapman DD, Charvet P *et al*.** From rivers to ocean basins: The role of ocean barriers and philopatry in the genetic structuring of a cosmopolitan coastal predator. Ecol Evol. 2023; 13(2):e9837. https://doi.org/10.1002/ece3.9837
- **Diario Oficial de la Federación (DOF).** Decreto por el que se declara como área natural protegida con el carácter de área de protección de flora y fauna, la región conocida como Laguna de Términos, ubicada en los municipios de Carmen, Palizada y Champotón, Estado de Campeche [Internet]. Ciudad de México: Secretaría de Gobernación; 1994. Available from: https://dof.gob.mx/nota_detalle.php?codigo=4700946&fecha=06/06/1994&print=true
- **Diario Oficial de la Federación (DOF).** Aviso por el que se da a conocer el Programa de Manejo del Area de Protección de Flora y Fauna, de la zona conocida como Laguna de Términos, ubicada en los municipios de Carmen, Palizada y Champotón, Camp., con el fin de dar cumplimiento a lo dispuesto en los artículos 65 y 66 de la Ley General del Equilibrio Ecológico y la Protección al Ambiente [Internet]. Ciudad de México: Secretaría de Gobernación; 1997. Available from: https://www.dof.gob.mx/nota_detalle.php?codigo=4882273&fecha=04/06/1997#gsc.tab=0
- **Diario Oficial de la Federación (DOF).** Acuerdo por el que se da a conocer el Plan de Manejo Pesquero de Tiburones y Rayas del Golfo de México y Mar Caribe. [Internet]. Ciudad de México: Secretaría de Gobernación; 2022. Available from: https://dof.gob.mx/nota_detalle.php?codigo=5654592&fecha=09/06/2022#gsc.tab=0

- **Dinkel TM, Sánchez-Lizaso JL.** Involving stakeholders in the evaluation of management strategies for shortfin mako *(Isurus oxyrinchus*) and blue shark (*Prionace glauca*) in the Spanish longline fisheries operating in the Atlantic Ocean. Mar Policy. 2020; 120:104124. https://doi.org/10.1016/j.marpol.2020.104124
- **Dulvy NK, Pacoureau N, Matsushiba JH, Yan HF, VanderWright WJ, Rigby CL *et al*.** Ecological erosion and expanding extinction risk of sharks and rays. Science. 2024; 386(6726):eadn1477. https://doi.org/10.1126/science.adn1477
- **Dulvy NK, Pacoureau N, Rigby CL, Pollom RA, Jabado RW, Ebert DA *et al*.** Overfishing drives over one-third of all sharks and rays toward a global extinction crisis. Curr Biol. 2021; 31(21):4773–87. https://doi.org/10.1016/j.cub.2021.08.062
- **Dulvy NK, Simpfendorfer CA, Davidson LN, Fordham SV, Bräutigam A, Sant G *et al*.** Challenges and priorities in shark and ray conservation. Curr Biol. 2017; 27(11):R565–72. https://doi.org/10.1016/j.cub.2017.04.038
- **Ebert DA, Dando M, Fowler SL.** Sharks of the world. A complete guide. Princeton, New Jersey: Princeton University Press; 2021.
- **Ehemann NR, González-González LD, Tagliafico A, Weigmann S.** Updated taxonomic list and conservation status of chondrichthyans from the exclusive economic zone of Venezuela, with first generic and specific records. J Fish Biol. 2019; 95(3):753–71. https://doi.org/10.1111/jfb.14061
- **Espinosa-Pérez H, Castro-Aguirre JL, Huidobro-Campos LH.** Listados faunísticos de México. IX. Catálogo sistemático de tiburones (Elasmobranchii: Selachimorha). México, D.F.: Universidad Nacional Autónoma de México; 2004.
- **Espinoza M, Díaz E, Angulo A, Hernández S, Clarke TM.** Chondrichthyan diversity, conservation status, and management challenges in Costa Rica. Front Mar Sci. 2018; 5:85. https://doi.org/10.3389/fmars.2018.00085
- **Esselman PC, Opperman JJ.** Overcoming information limitations for the prescription of an environmental flow regime for a Central American river. Ecol Soc. 2010; 15(1):6. Available from: http://www.ecologyandsociety.org/vol15/iss1/art6/
- **Feitosa LM, Martins APB, Nunes JLS.** New record of *Carcharhinus leucas* (Valenciennes, 1839) in an equatorial river system. Mar Biodivers Rec. 2016; 9(1):87. https://doi.org/10.1186/s41200-016-0094-6
- **Feitosa LM, Nunes JLS.** A new record of *Carcharhinus leucas* in an Amazonian river system. Bol Lab Hidrobiol. 2020; 30(1):62–67. http://dx.doi.org/10.18764/1981-6421e2020.6
- **Ferreira EJG, Zuanon J, Santos GMD.** A list of commercial fish species from Santarém, State of Pará, Brazil. Naga ICLARM Q. 1996; 19(3):41 44. Available from: https://core.ac.uk/reader/11023710
- **Foco Informativo, editors.** Capturan un tiburón en el Lago de Maracaibo [Internet]. Caracas: Foco Informativo; 2022. Available from: https://focoinformativo.com/capturan-un-tiburon-en-el-lago-de-maracaibo
- **Fogliarini CO, Giglio VJ, Bender MG, Ferreira CE.** Multidecadal fishers' knowledge reveals overexploitation of sharks in southeastern Brazil. Neotrop Ichthyol. 2024; 22(1):e230087. https://doi.org/10.1590/1982-0224-2023-0087
- **Froeschke JT, Froeschke BF, Stinson CM.** Long-term trends of bull shark (*Carcharhinus leucas*) in estuarine waters of Texas, USA. Can J Fish Aquat Sci. 2013; 70(1):13–21. https://doi.org/10.1139/cjfas-2012-0037
- **Fundación Defensores de la Naturaleza.** Refugio de Vida Silvestre Bocas del Polochic. II. Plan Maestro 2003–2007. Guatemala City: Defensores de la Naturaleza; 2002. Available from: https://defensores.org.gt/wp-content/uploads/Plan-Maestro-Bocas-del-Polochic.pdf
- **Galván-Magaña F, Abitia-Cárdenas LA, Rodríguez-Romero J, Pérez-España H, Chávez-Ramos H.** Lista sistemática de los peces de la Isla Cerralvo, Baja California Sur, México. Cienc Mar. 1996; 22(3):295–311. http://dx.doi.org/10.7773/cm.v22i3.863
- **Galván-Magaña F, Nienhuis HJ, Klimley AP.** Seasonal abundance and feeding habits of sharks of the Lower Gulf of California, Mexico. Calif Fish Game. 1989; 75(2):74–84. Available from: https://www.biodiversitylibrary.org/itempdf/72529

- **Garrick JAF.** Sharks of the genus *Carcharhinus*. NOAA Tech Rep NMFS, Circ. 1982; 445:1–194. Available from: https://spo.nmfs.noaa.gov/sites/default/files/legacy-pdfs/CIRC445.pdf
- **Gausmann P.** Synopsis of global fresh and brackish water occurrences of the bull shark *Carcharhinus leucas* Valenciennes, 1839 (Pisces: Carcharhinidae), with comments on distribution and habitat use. Integr Syst: Stuttgart Contrib Nat Hist. 2021; 4(1):55–213. http://doi.org/10.18476/2021.423083
- **Gausmann P.** Who´s the biggest fish in the pond? The story of bull sharks (*Carcharhinus leucas*) in an Australian golf course lake, with deliberations on this species´ longevity in low salinity habitats. Mar Fish Sci. 2024; 37(1):5–25. https://doi.org/10.47193/mafis.3712024010105
- **Gausmann P, Hasan V.** New inland records of the bull shark *Carcharhinus leucas* from Sumatra, Indonesia. Mar Fish Sci. 2022; 35(3):437–44. https://doi.org/10.47193/mafis.3532022010905
- **Gausmann P, Tavares R, Sanchéz L, Barros T, Gonzalez-Pestana A, Rohner CA.** Important Shark and Ray Area (ISRA) – Area of Interest (AoI): Lake Maracaibo AoI Factsheet. Dubai; 2025. Available from: https://doi.org/10.13140/rg.2.2.10133.03041
- **Gibson KJ, Streich MK, Topping TS, Stunz GW.** Utility of citizen science data: A case study in land-based shark fishing. PLoS ONE. 2019; 14(12):e0226782. https://doi.org/10.1371/journal.pone.0226782
- **Gill T, Bransford JF.** Synopsis of the fishes of Lake Nicaragua. Proc Acad Nat Sci Philad. 1877; 29:175-91. Available from: https://www.jstor.org/stable/4060186
- **Glaus KBJ, Appleyard SA, Stockwell B, Brunnschweiler JM, Shivji M, Clua E *et al*.** Insights into insular isolation of the Bull shark, *Carcharhinus leucas* (Müller and Henle, 1839), in Fijian waters. Front Mar Sci. 2020; 7:586015. http://doi.org/10.3389/fmars.2020.586015
- **Godin AC, Worm B.** Keeping the lead: how to strengthen shark conservation and management policies in Canada. Mar Policy. 2010; 34(5):995–1001. https://doi.org/10.1016/j.marpol.2010.02.006
- **Gonzáles-Acosta AF, Ruiz-Campos G, Balart EF.** Composition and zoogeography of fishes in mangrove ecosystems of Baja California Sur, México. In: Rodriguez RR, Gonzáles-Acosta AF, Muñiz-Salazar R, editors. The arid mangrove forest from Baja California Peninsula. New York: Nova Publishers; 2015. p.63–80. Available from: https://www.researchgate.net/publication/271076944_Composition_and_zoogeography_of_fishes_in_Mangrove_ecosystems_of_Baja_California_Sur_Mexico
- **Gunter G.** Marine fishes of Panama as related to the canal. Gulf Res Rep. 1979; 6(3):267–73. https://doi.org/10.18785/grr.0603.07
- **Hacohen-Domené A, Polanco-Vásquez F, Estupiñan-Montaño C, Graham RT.** Description and characterization of the artisanal elasmobranch fishery on Guatemala's Caribbean coast. PLoS ONE. 2020; 15(1):e0227797. https://doi.org/10.1371/journal.pone.0227797
- **Hagberg AH.** Informe sobre las investigaciones preliminaries en el Lago de Nicaragua. San Salvador: Proyecto Regional de Desarrollo Pesquero en Centro America; 1968.
- **Haig JA, Lambert GI, Sumpton WD, Mayer DG, Werry JM.** Habitat features influence catch rates of near-shore bull shark (*Carcharhinus leucas*) in the Queensland Shark Control Program, Australia 1996–2012. Estuar Coast Shelf Sci. 2018; 200:289–300. https://doi.org/10.1016/j.ecss.2017.11.013
- **Hammerschlag N, McDonnell LH, Rider MJ, Street GM, Hazen EL, Natanson LJ *et al*.** Ocean warming alters the distributional range, migratory timing, and spatial protections of an apex predator, the tiger shark (*Galeocerdo cuvier*). Glob Change Biol. 2022; 28(6):1990–2005. https://doi.org/10.1111/gcb.16045
- **Hastings PA, Findley LT.** Marine fishes in the upper Gulf Biosphere Reserve, northern Gulf of California. In: Felger RS, Broyles W, editors. Dry borders. Great natural reserves of the Sonoran Desert. Salt Lake City: University of Utah Press; 2006. p.364-82.
- **Hays GC, Ferreira LC, Sequeira AM, Meekan MG, Duarte CM, Bailey H *et al*.** Key questions in marine megafauna movement ecology. Trends Ecol Evol. 2016; 31(6):463–75. https://doi.org/10.1016/j.tree.2016.02.015

- **Hernández-Fernández GM, Quintana B, Lara S, Santamaria F.** Captura de peces elasmobranquios provenientes de la pesca artesanal en las playas de Poneloya y las Peñitas, León, Nicaragua. Rev Iberoam Bioecon Cambio Clim. 2021; 7(14):1766–80. https://doi.org/10.5377/ribcc.v7i14.13007
- **Herre AWCT.** Fishes of the Crane Pacific expedition. Publ Field Mus Nat Hist, Zool Ser. 1936; 21(353):1–472. Available from: https://www.biodiversitylibrary.org/item/20563#page/9/mode/1up
- **Heupel MR, Carlson JK, Simpfendorfer CA.** Shark nursery areas: concepts, definition, characterization and assumptions. Mar Ecol Prog Ser. 2007; 337:287–97. https://doi.org/10.3354/meps337287
- **Heupel MR, Simpfendorfer CA.** Movement and distribution of young bull sharks *Carcharhinus leucas* in a variable estuarine environment. Aquat Biol. 2008; 1:277-89. https://doi.org/10.3354/ab00030
- **Heupel MR, Simpfendorfer CA.** Estuarine nursery areas provide a low-mortality environment for young bull sharks *Carcharhinus leucas*. Mar Ecol Prog Ser. 2011; 433:237 44. https://doi.org/10.3354/meps09191
- **Heupel MR, Simpfendorfer CA, Espinoza M, Smoothey AF, Tobin A, Peddemors V.** Conservation challenges of sharks with continental scale migrations. Front Mar Sci. 2015; 2(12):1–07. https://doi.org/10.3389/fmars.2015.00012
- **Hildebrand SF.** The Panama Canal as a passageway for fishes, with lists and remarks on the fishes and invertebrates observed. Zool. 1939; 24:15–45. Available from: http://www.bio-nica.info/biblioteca/Hildebrand1939PanamaCanal.pdf
- **Howe JC, Springer VG.** Catalog of type specimens of recent fishes in the National Museum of Natural History, Smithsonian Institution, 5: Sharks (Chondrichthyes: Selachii). Smithson Contrib Zool. 1993; 540:1–19. https://doi.org/10.5479/si.00810282.540
- **Hoyos-Padilla EM, Casanova-Santamaría I, Loria-Correa JC, Sulikowski J.** The successful use of a submersible ultrasound to confirm pregnancy on free swimming bull sharks, *Carcharhinus leucas*, in a provisioned shark site. Front Mar Sci. 2023; 10:1193563. https://doi.org/10.3389/fmars.2023.1193563
- **Información Puntual, editors.** Depredador del mar regresa al Lago de Nicaragua [Internet]. Managua: Información Puntual; 2020. Available from: https://ipnicaragua.com/depredador-del-mar-regresa-al-lago-de-nicaragua
- **Iqbal M, Nurnawati E, Setiawan A, Dahlan Z, Yustian I.** First photographic inland records of bull shark *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae) in Sumatran waters, Indonesia. Ecol Montenegrina. 2019a; 22:171–76. https://doi.org/10.37828/em.2019.22.14
- **Iqbal M, Setiawan A, Yustian I.** First inland record of bull shark *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae) in Indonesian Borneo. Ecol Montenegrina. 2019b; 24:52–57. https://doi.org/10.37828/em.2019.24.9
- **Jabado RW, García-Rodríguez E, Kyne PM, Charles R, Gonzalez Pestana A, Priest MA *et al*.** Central and South American Pacific: a regional compendium of Important Shark and Ray Areas. Dubai: IUCN SSC Shark Specialist Group; 2023. https://doi.org/10.59216/ssg.isra.2023.r12
- **Jara-Aguirre NG.** Using steroid hormone concentrations to assess the reproductive cycle of the bull shark, *Carcharhinus leucas*, in Southern Florida. [MSc Thesis]. Phoenix: Arizona State University; 2021. Available from: https://hdl.handle.net/2286/R.I.63429
- **Jensen NH.** Reproduction of the bull shark, *Carcharhinus leucas*, in the Lake Nicaragua-Rio San Juan system. In: Thorson TB, editor. Investigations of the ichthyofaunal of Nicaraguan lakes. Lincoln: University of Nebraska-Lincoln; 1976. p.539-59. Available from: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1039&context=ichthynicar
- **Jézéquel C, Tedesco PA, Bigorne R, Maldonado-Ocampo JA, Ortega H, Hidalgo M *et al*.** A database of freshwater fish species of the Amazon Basin. Sci Data. 2020; 7(1):96. https://doi.org/10.1038/s41597-020-0436-4
- **Jorgensen SJ, Micheli F, White TD, Van Houtan KS, Alfaro-Shigueto J, Andrzejaczek S *et al*.** Emergent research and priorities for shark and ray conservation. Endanger Species Res. 2022; 47:171–203. https://doi.org/10.3354/esr01169

- **Kennedy WP.** Some additions to the fauna of Iraq. J Bombay Nat Hist Soc. 1937; 39(4):745–49. Available from: https://biostor.org/reference/208729
- **Kyne PM, Carlson JK, Ebert DA, Fordham SV, Bizzarro JJ, Graham RT, editors.** The conservation status of North American, Central American, and Caribbean chondrichthyans. Vancouver: IUCN/SSC Shark Specialist Group; 2012. Available from: https://portals.iucn.org/library/sites/library/files/documents/2012-046.pdf
- **Lara-Lizardi F, Castro E, Barajas VL, Morales JM, Hoyos-Padilla EM, Ketchum J.** Seasonal occurrence and individual variability of bull sharks, *Carcharhinus leucas*, in a marine reserve of the southwestern Gulf of California. PeerJ. 2024; 12:e17192. https://doi.org/10.7717/peerj.17192
- **Lara-Lizardi F, Hoyos-Padilla EM, Klimley AP, Grau M, Ketchum JT.** Movement patterns and residency of bull sharks, *Carcharhinus leucas*, in a marine protected area of the Gulf of California. Environ Biol Fish. 2022; 105:1765–79. https://doi.org/10.1007/s10641-022-01223-x
- **Laurrabaquio-Alvarado NS, Díaz-Jaimes P, Hinojosa-Álvarez S, Blanco-Parra MDP, Adams DH, Pérez-Jiménez JC *et al*.** Mitochondrial DNA genome evidence for the existence of a third divergent lineage in the western Atlantic Ocean for the bull shark (*Carcharhinus leucas*). J Fish Biol. 2021; 99(1):275–82. https://doi.org/10.1111/jfb.14698
- **Laurrabaquio-Alvarado NS, Islas-Villanueva V, Adams DH, Uribe-Alcocer M, Alvarado-Bremer JR, Díaz-Jaimes P.** Genetic evidence for regional philopatry of the bull shark (*Carcharhinus leucas*), to nursery areas in estuaries of the Gulf of Mexico and western North Atlantic Ocean. Fish Res. 2019; 209:67-74. https://doi.org/10.1016/j.fishres.2018.09.013
- **Lea JSE, Humphries NE, Clarke CR, Sims DW.** To Madagascar and back: Long-distance, return migration across open ocean by a pregnant female bull shark *Carcharhinus leucas*. J Fish Biol. 2015; 87(6):1313–21. https://doi.org/10.1111/jfb.12805
- **Lédée EJI, Heupel MR, Taylor MD, Harcourt RD, Jaine FRA, Huveneers C *et al*.** Continental-scale acoustic telemetry and network analysis reveal new insights into stock structure. Fish Fish. 2021; 22(5):987–1005. https://doi.org/10.1111/faf.12565
- **De la Llata Quiroga E, Arauz R, Tripp Valdez A, Porras Murillo L, Parallada MS, Sánchez-Murillo R *et al*.** Trophic ecology of juvenile bull sharks (*Carcharhinus leucas*) in the Coyote estuary, Costa Rica. J Fish Biol. 2023; 102(3):669–79. https://doi.org/10.1111/jfb.15313
- **Lofthus AJ, Beach-Mehrotra M, Fisher MR, Wozniak JR, Matich P.** Factors influencing the nursery dynamics of bull sharks (*Carcharhinus leucas*) in two estuaries along the Texas coast. Mar Ecol Prog Ser. 2024; 728:43–58. https://doi.org/10.3354/meps14495
- **López-Garro A, Zanella I.** Residency of bull sharks, *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae), at San Pedrillo Islet in Islas Murciélago, North Pacific of Costa Rica. Rev Biol Trop. 2021; 69(2):246–55. https://doi.org/10.15517/rbt.v69iS2.48321
- **Lubitz N, Bradley M, Sheaves M, Hammerschlag N, Daly R, Barnett A.** The role of context in elucidating drivers of animal movement. Ecol Evol. 2022; 12(7):e9128. https://doi.org/10.1002/ece3.9128
- **Lutz Í, Santos PE, Campos R, Oliveira CACD, Wosnick N, Evangelista-Gomes G *et al*.** Fishing profile and commercial landings of shark and batoids in a global elasmobranchs conservation hotspot. An Acad Bras Ciênc. 2024; 96(2):e20231083. https://doi.org/10.1590/0001-3765202420231083
- **Marcos-Camacho SA, Nalesso E, Caamal-Madrigal JA, Fulton S.** Caracterización de la pesquería de tiburón en el norte de Quintana Roo, México. Cienc Pesq. 2016; 24:153–56. Available from: https://www.cobi.org.mx/wp-content/uploads/2017/07/Caracterizacion-pesqueria-de-tiburon-en-Nte-de-QRoo.pdf
- **Martínez-Candelas IA, Pérez-Jiménez JC, Espinoza-Tenorio A, McClenachan L, Méndez-Loeza I.** Use of historical data to assess changes in the vulnerability of sharks. Fish Res. 2020; 226:105526. https://doi.org/10.1016/j.fishres.2020.105526

- **Martínez-Ortíz J, Carrera-Fernándes M, Galván-Magaňa F, Estupiňan-Montaňo C, Cedeňo-Figueroa L.** Biología, pesquería y comercialización del tiburón come perro, *Carcharhinus leucas* (Müller & Henle, 1839) en aguas del Ecuador. In: Martínez-Ortíz J, Galván-Maga a F, editors. Tiburones en el Ecuador: casos de estudio. Manta: EPESPO–PMRC Publishing; 2007. p.90-98.
- **Martínez-Sánchez JC, Maess J-M, van den Berghe E, Morales S, Castañeda EA.** Biodiversidad zoológica en Nicaragua. Una estrategia nacional para su conservación. Managua: Ministerio del Ambiente y los Recursos Naturales; 2001. Available from: http://www.bio-nica.info/biblioteca/BiodiversidadNicaragua.pdf
- **Martínez-Serrano I, Canales-Espinosa D, Vargas-Hernández JM, Sánchez-Castro JL, Hoyos-Padilla M.** An adapted technique to detect sharks in moody waters. In: Díaz Sánchez AW, editor. VI Simposium Nacional de Tiburones y Rayas. México, DF: Sociedad Mexicana de Peces Cartilaginosos A.C.; 2014. p.106–08. http://dx.doi.org/10.13140/2.1.4158.7200
- **Matich P, Heithaus MR.** Effects of an extreme temperature event on the behavior and age structure of an estuarine top predator, *Carcharhinus leucas*. Mar Ecol Prog Ser. 2012; 447:165-78. https://doi.org/10.3354/meps09497
- **Matich P, Heithaus MR.** Individual variation in ontogenetic niche shifts in habitat use and movement patterns of a large estuarine predator (*Carcharhinus leucas*). Oecologia. 2015; 178(2):347-59. https://doi.org/10.1007/s00442-015-3253-2
- **Matich P, Nowicki RJ, Davis J, Mohan JA, Plumlee JD, Strickland BA *et al*.** Does proximity to freshwater refuge affect the size structure of an estuarine predator (*Carcharhinus leucas*) in the north-western Gulf of Mexico? Mar Freshw Res. 2020a; 71(11):1501–16. https://doi.org/10.1071/MF19346
- **Matich P, Plumlee JD, Bubley W, Curtis TH, Drymon JM, Mullins LL *et al*.** Long-term effects of climate change on juvenile bull shark migratory patterns. J Anim Ecol. 2024; 93(10):1445–61. https://doi.org/10.1111/1365-2656.14140
- **Matich P, Shipley ON, Weideli OC.** Quantifying spatial variation in isotopic baselines reveals size-based feeding in a model estuarine predator: implications for trophic studies in dynamic ecotones. Mar Biol. 2021; 168(7):108. https://doi.org/10.1007/s00227-021-03920-0
- **Matich P, Strickland BA, Heithaus MR.** Long-term monitoring provides insight into estuarine top predator (*Carcharhinus leucas*) resilience following an extreme weather event. Mar Ecol Prog Ser. 2020b; 639:169-83. https://doi.org/10.3354/meps13269
- **McCosker JE, Dawson CE.** Biotic passage through the Panama Canal, with particular reference to fishes. Mar Biol. 1975; 30:343–51. https://doi.org/10.1007/BF00390639
- **McDavitt MT.** Lake Nicaragua revisited: conversations with a former sawfish fisherman. Shark News. 2002; 14:5. Available from: https://www.iucnssg.org/uploads/5/4/1/2/54120303/sn14_march2002.pdf
- **Medina-Gómez I, Villalobos-Zapata GJ, Herrera-Silveira JA.** Spatial and temporal hydrological variations in the inner estuaries of a large coastal lagoon of the southern Gulf of Mexico. J Coast Res. 2015; 31(6):1429–38. https://doi.org/10.2112/JCOASTRES-D-13-00226.1
- **Michot TC, Boustany RG, Arrivillaga A, Perez B.** Impacts of Hurricane Mitch on water quality and sediments of Lake Izabal, Guatemala. USGS Open File Rep. 2002; 180(3):1–20. https://doi.org/10.3133/ofr03180
- **Miller RR, Minckley WL, Norris SM.** Freshwater fishes of Mexico, 490 pp.; Chicago: The University of Chicago Press; 2006.
- **Miller RR, Minckley WL, Norris SM.** Peces dulceacuícolas de México. México, D.F.: Comisión Nacional para el Conocimiento & Uso de la Biodiversidad, Sociedad Ictiológica Mexicana A. C., El colegio de la Frontera Sur y Consejo de los Peces del Desierto México-Estados Unidos; 2009.
- **Misra KS, Menon MAS.** On the distribution of the elasmobranchs and chimaeras of the Indian region in relation to the mean annual isotherms. Rec Indian Mus. 1955; 53:73–86. Available from: http://recordsofzsi.com/index.php/zsoi/article/download/162023/113182

- **Montalvo C, Aguilar CA, Amador LE, Cerón JG, Cerón RM, Anguebes F *et al*.** Metal contents in sediments (Cd, Cu, Mg, Fe, Mn) as indicators of pollution of Palizada River, Mexico. Environ Pollut. 2014; 3(4):89–98. https://doi.org/10.5539/ep.v3n4p89
- **Montoya RV, Thorson TB.** The bull shark (*Carcharhinus leucas*) and largetooth sawfish (*Pristis perotteti*) in Lake Bayano, a tropical man-mad impoundment in Panama. Environ Biol Fish. 1982; 7(4):341-47. https://doi.org/10.1007/BF00005568
- **Moore AB.** Identification of critical habitat in a data-poor area for an endangered aquatic apex predator. Biol Conserv. 2018; 220:161–69. https://doi.org/10.1016/j.biocon.2018.02.013
- **Morgan AC, Burgess GH.** Fishery-dependent sampling: total catch, effort and catch composition. FAO Fish Tech Paper. 2005; 474:182–200.
- **Moura RL, Amado-Filho GM, Moraes FC, Brasileiro PS, Salomon PS, Mahiques MM *et al*.** An extensive reef system at the Amazon River mouth. Sci Adv. 2016; 2(4):e1501252. https://doi.org/10.1126/sciadv.1501252
- **Mourier J, Soria M, Blaison A, Simier M, Certain G, Demichelis A *et al*.** Dynamic use of coastal areas by bull sharks and the conciliation of conservation and management of negative human–wildlife interactions. Aquat Conserv: Mar Freshw Ecosyst. 2021; 31(10):2926–37. https://dx.doi.org/10.1002/aqc.3674
- **Mouton TL, Gonzalez-Pestana A, Rohner CA, Charles R, García-Rodríguez E, Kyne PM *et al*.** Shortfalls in the protection of Important Shark and Ray Areas undermine shark conservation efforts in the Central and South American Pacific. Mar Policy. 2025; 171:106448. https://doi.org/10.1016/j.marpol.2024.106448
- **Mullins L, Cartwright J, Dykstra SL, Evans K, Mareska J, Matich P *et al*.** Warming waters lead to increased habitat suitability for juvenile bull sharks (*Carcharhinus leucas*). Sci Rep. 2024; 14(1):4100. https://doi.org/10.1038/s41598-024-54573-0
- **Myers GS.** Sharks and sawfishes of the Amazon. Copeia. 1952; 1952(4):268-69. https://doi.org/10.2307/1439279
- **Nascimento MC, Santos SR, Vianna M.** A bibliometric analysis concerning local ecological knowledge on elasmobranchs and chimaeras. Ethnobiol Conserv. 2023; 12:25. https://doi.org/10.15451/ec2023-12-12.25-1-19
- **Natanson LJ, Adams DH, Winton MV, Maurer JR.** Age and growth of the bull shark in the Western North Atlantic Ocean. Trans Am Fish Soc. 2014; 143(3):732-43. http://dx.doi.org/10.1080/00028487.2014.892537
- **Neer JA, Thompson BA, Carlson JK.** Age and growth of *Carcharhinus leucas* in the northern Gulf of Mexico: incorporating variability in size at birth. J Fish Biol. 2005; 67(2):370–83. https://doi.org/10.1111/j.0022-1112.2005.00743.x
- **Nevill JEG, Bamboche D, Philoe H.** Record litter size for the bull shark, *Carcharhinus leucas* (Müller & Henle, 1839), documented in the Seychelles. WIO J Mar Sci. 2013; 12(1):85. Available from: https://www.ajol.info/index.php/wiojms/article/view/104265/96156
- **Nicaragua Investiga, editors.** Liberan pez sierra en el Río San Juan [Internet]. Managua: Nicaragua Investiga; 2022. Available from: https://nicaraguainvestiga.com/nacion/100543-liberan-pez-sierra-en-el-rio-san-juan
- **Niella YV, Afonso AS, Hazin FH.** Bioecology and movements of bull sharks, *Carcharhinus leucas*, caught in a long-term longline survey off northeastern Brazil. Neotrop Ichthyol. 2017; 15(3):e170106. https://doi.org/10.1590/1982-0224-20170106
- **Niella N, Raoult V, Gaston T, Goodman K, Harcourt R, Peddemors V *et al*.** Reliance of young sharks on threatened estuarine habitats for nutrition implies susceptibility to climate change. Estuar Coast Shelf Sci. 2022; 268:107790. https://doi.org/10.1016/j.ecss.2022.107790
- **NotiActual, editors.** Pescan Tiburones en el Lago de Maracaibo [Internet]. Caracas: NotiActual; 2022. Available from: https://www.notiactual.com/insolito-pescan-tiburones-en-el-lago-de-maracaibo
- **O'Connell CP, Gressle J, Crews J, King AA, He P.** Evaluating the effects of a SharkSafe Barrier shoreline deployment on bull shark (*Carcharhinus leucas*) behaviour. Aquat Conserv: Mar Freshw Ecosyst. 2022; 32(1):55–65. https://doi.org/10.1002/aqc.3732

- **Olivares-Rubio HF, Ontiveros-Cuadras JF, Celis-Hernández O, Salazar-Remigio L, Santiago-Pérez S, Girón-García MP *et al*.** Spatial distribution of PAHs, nickel, and vanadium in sediments from a large coastal lagoon near a petroleum extraction area in the southern Gulf of Mexico. Mar Poll Bull. 2024; 207:116901. https://doi.org/10.1016/j.marpolbul.2024.116901
- **Oliveira CDL, Ladle RJ, Silva Batista V.** Patterns and trends in scientific production on marine elasmobranchs: research hotspots and emerging themes for conservation. J Coast Conserv. 2023; 27(1):6. https://doi.org/10.1007/s11852-023-00937-z
- **Organización Nicaragüense Ambiental.** Aun hay tiburones de agua dulce en nuestro Gran Lago de Nicaragua [Internet]. Managua: Organización Nicaragüense Ambiental; 2014.
- **Osuka KE, Samoilys MA, Musembi P, Thouless CJ, Obota C, Rambahiniarison J.** Status and characteristics of sharks and rays impacted by artisanal fisheries: potential implications for management and conservation. Mar Fish Sci. 2025; 38(1):21–39. https://doi.org/10.47193/mafis.3812025010101
- **Pacoureau N, Carlson JK, Kindsvater HK, Rigby CL, Winker H, Simpfendorfer CA *et al*.** Conservation successes and challenges for wide-ranging sharks and rays. Proc Natl Acad Sci USA. 2023; 120(5):e2216891120. https://doi.org/10.1073/pnas.2216891120
- **Parreira MR, Nabout JC.** Hydropower plants as dispersal barriers in freshwater species distribution models: using restrictions through asymmetrical dispersal predictors. Environ Manage. 2023; 72:424–36. https://doi.org/10.1007/s00267-023-01812-1
- **Paz-Ríos CE, Sosa-López A, Torres-Rojas YE, Ramos-Miranda J, del Río-Rodríguez RE.** Fish species richness in the Terminos Lagoon: An occurrence data compilation of four sampling campaigns along a multidecadal series. Biodivers Data J. 2021; 9:e65317. https://doi.org/10.3897/BDJ.9.e65317
- **Peiris MAK, Kumara TP, Ranatunga RRMKP, Liu SYV.** Species composition and conservation status of shark from fishery landings and fish markets in Sri Lanka revealed by DNA barcoding. Fish Res. 2021; 242:106045. https://doi.org/10.1016/j.fishres.2021.106045
- **Pelicice FM, Agostinho AA, Akama A, Andrade Filho JD, Azevedo-Santos VM, Barbosa MVM *et al*.** Large-scale degradation of the Tocantins-Araguaia River basin. Environ Manage. 2021; 68:445–52. https://doi.org/10.1007/s00267-021-01513-7
- **Peña-Puch A, Pérez J, Munguía A, Espinoza A.** Sistemas socioecologicos como unidad de manejo: el caso de las pesquerías de Campeche, México. Econ Soc Territ. 2021; 21(65):113–45. https://doi.org/10.22136/est20211601
- **Pérez RC, Mondragón A.** Cocibolca o el Gran lago: una ecología del espíritu. Rev Tem Nicaragüenses. 2011; 43:38–45. Available from: https://www.enriquebolanos.org/media/publicacion/RevistaTemasNicaraguenses43noviembre2011.pdf
- **Pérez-Jiménez JC, Loeza M, Maestro I, Carranza M, Zimbrón C.** Análisis histórico de las pesquerías de elasmobranquios del sureste del Golfo de México. In: Sánchez AJ, Chiapa-Carrara X, Pérez RB, editors. Recursos acuáticos costeros del sureste Vol. II. Mérida, México: Universidad Nacional Autónoma de México; 2012. p.463–81. Available from: https://13048776-b8de-a43a-0eea-f0ffaac455cf.filesusr.com/ugd/ce3f84_56cf9d630978c886d0e5c80e-8c5953d0.pdf
- **Pérez-Jiménez JC, Mendez-Loeza I.** The small-scale shark fisheries in the southern Gulf of Mexico: Understanding their heterogeneity to improve their management. Fish Res. 2015; 172:96–104. https://doi.org/10.1016/j.fishres.2015.07.004
- **Pérez-Jiménez JC, Peña-Puch A, Méndez-Loeza I, Giard-Leroux A, Flores-Ramos E, López-Rasgado FJ.** Las pesquerías artesanales de elasmobranquios como parte de sistemas pesqueros complejos en el sur del Golfo de México. Cienc Pesq. 2016; 24(especial):113–24. Available from: https://www.gob.mx/cms/uploads/attachment/file/241947/10_Ciencia_Pesquera_24_especial.pdf
- **Pérez-Jiménez JC, Wakida-Kusunoki A, Hernández-Lazo C, Mendoza-Carranza M.** Shark-catch composition and seasonality in the data-poor small-scale fisheries of the southern Gulf of Mexico. Mar Freshw Res. 2020; 71(9):1182–93. https://doi.org/10.1071/MF19184

- **Pérez-Jiménez JC, Mendoza-Carranza M.** Occurrences of immature sharks in artisanal fisheries of the southern Gulf of Mexico. Arq Cien Mar. 2023; 56(1):1–12. https://doi.org/10.32360/acmar.v56i1.92055
- **Perry AL, Low PJ, Ellis JR, Reynolds JD.** Climate change and distribution shifts in marine fishes. Science. 2005; 308(5730):1912–15. https://doi.org/10.1126/science.1111322
- **Pillans RD.** The physiological ecology of the bull shark *Carcharhinus leucas* in the Brisbane River. [PhD Thesis]. Brisbane: University of Queensland; 2006. Available from: https://espace.library.uq.edu.au/view/UQ:158284
- **Piorski NM, Abreu JMDS, Serejo Saraiva AC, Nunes JLS.** Capítulo 2.4: Ictiofauna. In: Oliveira TGD, Piorski NM, Gonsioroski GH, Vieira OQ, Pavan D, Rebelo JMM *et al.*, editors. Diversidade Faunística do Maranhão: avaliação da composição, áreas prioritárias, ameaças e recomendações de ações para sua conservação. São Luís: Instituto Maranhense de Estudos Socioeconômicos e Cartográficos (IMESC); 2021. p.98–142. Available from: https://www.researchgate.net/publication/372189754_DIVERSIDADE_FAUNISTICA_DO_MARANHAO_AVALIACAO_DA_COMPOSICAO_AREAS_PRIORITARIAS_AMEACAS_E_RECOMENDACOES_DE_ACOES_PARA_SUA_CONSERVACAO
- **Pires G.** Tubarão-touro é encontrado por pescadores em Limoeiro do Ajuru [Internet]. São Paulo: O Liberal; 2022. Available from: https://www.oliberal.com/para/pescadores-de-limoeiro-do-ajuru-no-nordeste-paraense-encontram-tubarao-touro-1.572312
- **Pirog A, Ravigné V, Fontaine MC, Rieux A, Gilabert A, Cliff G *et al*.** Population structure, connectivity, and demographic history of an apex marine predator, the bull shark *Carcharhinus leucas*. Ecol Evol. 2019; 9(23):12980–3000. https://doi.org/10.1002/ece3.5597
- **Plotnikov IS, Aladin NV.** An overview of hybrid marine and lacustrine seas and saline lakes of the world. Lakes Reserv: Res Manag. 2011; 16(2):97–108. https://doi.org/10.1111/j.1440-1770.2011.00452.x
- **Pollerspöck J, Straube N.** Shark-references, World Wide Web electronic publication, Version 2024 [Internet]. Stephansposching: Shark References; 2024. Available from: https://shark-references.com/literature/listByAuthor/Thorson-T.B./
- **Postaire BD, Devloo-Delva F, Brunnschweiler JM, Charvet P, Chen X, Cliff G *et al*.** Global genetic diversity and historical demography of the Bull Shark. J Biogeogr. 2024; 51(4):632–48. https://doi.org/10.1111/jbi.14774
- **Rábago-Quiroz CH, González-Acosta AF, Ruiz-Campos G, Franco-López J, García-Borbón JA, Magaña JD.** Composition and zoogeography of marine-estuarine fish from a lagoon system in a temperate-tropical transition zone of the Eastern Pacific. Rev Mex Biodivers. 2024; 95:e955305. https://doi.org/10.22201/ib.20078706e.2024.95.5305
- **Ramos-Miranda J, Quiniou L, Flores-Hernandez D, Do-Chi T, Ayala-Perez L, Sosa-Lopez A.** Spatial and temporal changes in the nekton of the Terminos Lagoon, Campeche, Mexico. J Fish Biol. 2005; 66(2):513–30. https://doi.org/10.1111/j.0022-1112.2005.00619.x
- **Ramirez-Amaro SR, Cartamil D, Galvan-Magaña F, Gonzalez-Barba G, Graham JB, Carrera-Fernandez M *et al*.** The artisanal elasmobranch fishery of the Pacific coast of Baja California Sur, Mexico, management implications. Sci Mar. 2013; 77(3):473–87. https://doi.org/10.3989/scimar.03817.05A
- **Reis RE, Albert JS, Di Dario F, Mincarone MM, Petry P, Rocha LA.** Fish biodiversity and conservation in South America. J Fish Biol. 2016; 89(1):12–47. https://doi.org/10.1111/jfb.13016
- **Reyes-Bonilla H, Ayala-Bocos A, Melo FJFR, Zepeta-Vilchis R, Asúnsolo-Rivera A, Ketchum JT.** A bibliographic and field record chronology of sharks at Cabo Pulmo National Park, Gulf of California. CICIMAR Oceánides. 2016; 31(1):55–57. https://doi.org/10.37543/oceanides.v31i1.160
- **Rigby CL, Espinoza M, Derrick D, Pacoureau N, Dicken M.** *Carcharhinus leucas*. The IUCN red list of threatened species. 2021:e.T39372A2910670. https://dx.doi.org/10.2305/IUCN.UK.2021-2.RLTS.T39372A2910670.en

- **Rivadeneira MM, Hunt G, Roy K.** The use of sighting records to infer species extinctions: an evaluation of different methods. Ecology. 2009; 90(5):1291–300. https://doi.org/10.1890/08-0316.1
- **Robertson DR, Grove JS, McCosker JE.** Tropical transpacific shore fishes. Pac Sci. 2004; 58(4):507-65. https://doi.org/10.1353/psc.2004.0041
- **Roff G, Brown CJ, Priest MA, Mumby PJ.** Decline of coastal apex shark populations over the past half century. Commun Biol. 2018; 1(1):223. https://doi.org/10.1038/s42003-018-0233-1
- **Rojas MJR, Campos MJ, Segura A, Mug VM, Campos R, Rodríguez O.** Shark fisheries in Central America: a review and update. Uniciencia. 2000; 17(1):49-56. Available from: https://www.revistas.una.ac.cr/index.php/uniciencia/article/view/5706
- **Rolls RJ, Stewart-Koster B, Ellison T, Faggotter S, Roberts DT.** Multiple factors determine the effect of anthropogenic barriers to connectivity on riverine fish. Biodivers Conserv. 2014; 23:2201–20. https://doi.org/10.1007/s10531-014-0715-5
- **Rosales-Melgar MA, Santana-Morales O, Rodríguez-Fuentes M, Zepeda-Domínguez JA, Pérez-Jiménez JC, Areano-Barillas E.** Elasmobranchs small-scale fishery in Guatemala: socioeconomic aspects and value chain structure. SSHO. 2024; 10:100970. https://doi.org/10.1016/j.ssaho.2024.100970
- **Rosenblatt AE, Heithaus MR, Mather ME, Matich P, Nifong JC, Ripple WJ *et al*.** The roles of large top predators in coastal ecosystems: New insights from long term ecological research. Oceanography. 2013; 26(3):156–67. http://dx.doi.org/10.5670/oceanog.2013.59
- **Rosenblatt RH, Baldwin WJ.** A review of the Eastern Pacific sharks of the genus *Carcharhinus*, with a redescription of *C. malpeolensis* (Fowler) and California records of *C. remotus* (Duméril). Calif Fish Game. 1958; 44(2):137–59. Available from: www.archive.org/download/californiafishga44_2cali/californiafishga44_2cali.pdf
- **Rubio-Cisneros NT, Martínez-Candelas IA, Ordaz-García D, Pérez-Jiménez JC, Jiménez-Cano NG, Glover JB *et al*.** Interdisciplinary science and fishers' local ecological knowledge of sawfishes in the Yucatán Peninsula. Aquat Conserv: Mar Freshw Ecosyst. 2023; 33(9):897–916. https://doi.org/10.1002/aqc.3981
- **Ruelas-Inzunza JR, Escobar-Sánchez O, Páez-Osuna F.** Mercury in fish, crustaceans, and mollusks from estuarine areas in the Pacific Ocean and Gulf of Mexico under varying human impact. In: Amezcua F, Bellgraph B, editors. Fisheries management of Mexican and Central American estuaries. Heidelberg, New York, London: Springer; 2014. p.39-50. https://doi.org/10.1007/978-94-017-8917-2_3
- **Ruelas-Inzunza JR, Páez-Osuna F.** Mercury in fish and shark tissues from two coastal lagoons in the Gulf of California, Mexico. Bull Environ Contam Toxicol. 2005; 74(2):294–300. https://doi.org/10.1007/s00128-004-0583-x
- **Ruelas-Inzunza JR, Páez-Osuna F.** Essential and toxic metals in nine fish species for human consumption from two coastal lagoons in the Eastern Gulf of California. J Environ Sci Health A. 2007; 42(10):1411–16. https://doi.org/10.1080/10934520701480615
- **Sabbagh SM, Hickey GM.** Social factors affecting sustainable shark conservation and management in Belize. Sustainability. 2019; 12(1):40. https://doi.org/10.3390/su12010040
- **Sabaj MH.** Codes for Natural History Collections in Ichthyology and Herpetology. Copeia. 2020; 108(3):593–669. https://doi.org/10.1643/ASIHCODONS2020
- **Saldaña-Ruiz LE.** The artisanal shark fishery in the Gulf of California: Historical catch reconstruction and vulnerability of shark species to the fishery. [PhD Thesis]. Ensenada, Baja California: Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California; 2017. Available from: https://cicese.repositorioinstitucional.mx/jspui/bitstream/1007/1443/1/tesis_Salda%c3%b1a_Ruiz_Luz_Erandi_12_julio_2017.pdf

- **Saldaña-Ruiz LE, Flores-Guzmán A, Cisneros-Soberanis F, Cuevas-Gómez GA, Gastélum-Nava E, Rocha-Tejeda L *et al*.** A risk-based assessment to advise the responsible consumption of invertebrates, elasmobranch, and fishes of commercial interest in Mexico. Front Mar Sci. 2022; 9:866135. https://doi.org/10.3389/fmars.2022.866135
- **Saldaña-Ruiz LE, Sosa-Nishizaki O, Cartamil D.** Historical reconstruction of Gulf of California shark fishery landings and species composition, 1939–2014, in a data-poor fishery context. Fish Res. 2017; 195:116–29. https://doi.org/10.1016/j.fishres.2017.07.011
- **Salomón-Aguilar CA, Villavicencio-Garayzar CJ, Reyes-Bonilla H.** Shark breeding grounds and seasons in the Gulf of California: fishery management and conservation strategy. Cienc Mar. 2009; 35(4):369–88. https://doi.org/10.7773/cm.v35i4.1435
- **Sánchez Crispín Á, Urbina Bravo MA, Frejomil EP.** Rasgos territoriales del turismo en la Isla de Ometepe, Nicaragua. Cuad Tur. 2008; 21:159–79. Available from: https://revistas.um.es/turismo/article/view/25031/24321
- **Sánchez L, Tavares R.** El Sistema de Maracaibo y su Importancia como Área de Criadero de Tiburones. Proc Gulf Caribb Fish Inst. 2010; 62:571–74. Available from: https://proceedings.gcfi.org/wp-content/uploads/2015/01/gcfi_62-81.pdf
- **Saunders CB, Holloway AD, Handley Jr. CO.** A fish and wildlife survey of Guatemala. U.S. Fish Wildl Serv Spec Sci Rep. 1950; 5:1–162. Available from: http://www.nativefishlab.net/library/textpdf/20529.pdf
- **Schmidt JC, Bruckerhoff L, Salehabadi H, Wang J.** Chapter 10: The Colorado River. In: Gupta A, editor. Large Rivers: Geomorphology and Management, Second Edition. Chichester: John Wiley & Sons; 2022. p.253–319. https://doi.org/10.1002/9781119412632.ch10
- **Schmidt JC, Yackulic CB, Kuhn E.** The Colorado river water crisis: Its origin and the future. WIREs Water. 2023; 10(6):e1672. https://doi.org/10.1002/wat2.1672
- **Schreiber L, Castellanos-Galindo GA, Robertson DR, Torchin M, Chavarria K, Laakmann S *et al*.** Environmental DNA (eDNA) reveals potential for interoceanic fish invasions across the Panama Canal. Ecol Evol. 2023; 13(1):e9675. https://doi.org/10.1002/ece3.9675
- **Schultz LP.** A further contribution to the ichthyology of Venezuela. Proc U S Natl Mus. 1949; 99(3235):1–211. https://doi.org/10.5479/si.00963801.99-3235.1
- **Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).** Programa de Acción para la Conservación de las Especies Tiburones y Rayas. México, D. F.: SEMARNAT/CONANP; 2018. Available from: https://www.gob.mx/cms/uploads/attachment/file/444011/PACE_Tiburones_y_Rayas.pdf
- **Sharpe DMT, León LF, González R, Torchin ME.** Tropical fish community does not recover 45 years after predator introduction. Ecol. 2017; 98(2):412–24. https://doi.org/10.1002/ecy.1648
- **Shea S, Slee B.** Meat on the menu and fins for export: Latin America's shark trade with Asia. The Hague, The Netherlands: Stichting IFAW (International Fund for Animal Welfare); 2024. Available from: https://cites.org/sites/default/files/documents/AC33%20Inf.%2024.pdf
- **Shell R, Gardner N.** Movement of the bull shark (*Carcharhinus leucas*) in the upper Mississippi River Basin, North America. Mar Fish Sci. 2021; 34(2):263–67. https://doi.org/10.47193/mafis.3422021010607
- **Sherman CS, Digel ED, Zubick P, Eged J, Haque AB, Matsushiba JH *et al*.** High overexploitation risk due to management shortfall in highly traded requiem sharks. Conserv Lett. 2023; 16(2):e12940. https://doi.org/10.1111/conl.12940
- **Sherman KD, Shultz AD, Dahlgren CP, Thomas C, Brooks E, Brooks A *et al*.** Contemporary and emerging fisheries in The Bahamas - Conservation and management challenges, achievements and future directions. Fish Manage Ecol. 2018; 25(5):319–31. https://doi.org/10.1111/fme.12299
- **Shiffman DS, Macdonald CC, Wallace SS, Dulvy NK.** The role and value of science in shark conservation advocacy. Sci Rep. 2021; 11(1):16626. https://doi.org/10.1038/s41598-021-96020-4

- **Silvano RA, Baird IG, Begossi A, Hallwass G, Huntington HP, Lopes PF.** Fishers' multidimensional knowledge advances fisheries and aquatic science. Trends Ecol Evol. 2023; 38(1):8–12. https://doi.org/10.1016/j.tree.2022.10.002
- **Simpfendorfer CA, Burgess GH.** Bull shark *Carcharhinus leucas* (Valenciennes, in Müller & Henle, 1839). In: Fowler SL, Cavanagh RD, Camhi M, Burgess GH, Cailliet GM, Fordham SV *et al*., editors. Sharks, rays and chimaeras: the status of the chondrichthyan fishes. Gland, Cambridge: IUCN/SSC Shark Specialist Group & IUCN; 2005. p.291-93. Available from: https://portals.iucn.org/library/efiles/documents/2005-029.pdf
- **Smith HM.** Sharks in Lake Nicaragua. Science. 1893; 22(555):166–67. https://doi.org/10.1126/science.ns-22.555.166
- **Smith SA, Bell G, Bermingham E.** Cross-Cordillera exchange mediated by the Panama Canal increased the species richness of local freshwater fish assemblages. Proc R Soc B. 2004; 271(1551):1889–96. https://doi.org/10.1098/rspb.2004.2796
- **Smith SE, Au DW, Show C.** Intrinsic rebound potentials of 26 species of Pacific sharks. Mar Freshw Res. 1998; 49(7):663–78. https://doi.org/10.1071/MF97135
- **Smoothey AF, Lee KA, Peddemors VM.** Longterm patterns of abundance, residency and movements of bull sharks (*Carcharhinus leucas*) in Sydney Harbour, Australia. Sci Rep. 2019; 9:18864. https://doi.org/10.1038/s41598-019-54365-x
- **Soto JMR, Mincarone MM.** Collections of the Museu Oceanográfico do Vale do Itajaí. I. Catalog of cartilaginous fishes (Myxini, Cephalaspidomorphi, Elasmobranchii, Holocephali). Mare Magnum. 2004; 2(1–2):1–125. Available from: https://www.univali.br/institucional/museu-oceanografico-univali/producao-cientifica/artigos-cientificos/Documents/2004-4.pdf
- **Soto JMR, Nisa-Castro-Neto W.** Revisão dos registros de tubarão touro, *Carcharhinus leucas* (Valenciennes 1839) (Chondrichtyes, Carcharhinidae), em rios e lagunas brasileiras. In: Resumos expandidos da 11ª Semana Nacional de Oceanografia. Rio Grande: Fundação Universidade do Rio Grande; 1998. p.314-16.
- **Soto-Galera E, Piera J, López P.** Spatial and temporal land cover changes in Terminos Lagoon Reserve, Mexico. Rev Biol Trop. 2010; 58(2):565–75. https://doi.org/10.15517/rbt.v58i2.5229
- **Souza-Araujo J, Souza-Junior OG, Guimarães-Costa A, Hussey NE, Lima MO, Giarrizzo T.** The consumption of shark meat in the Amazon region and its implications for human health and the marine ecosystem. Chemosphere. 2021; 265:129132. https://doi.org/10.1016/j.chemosphere.2020.129132
- **Starks EC.** The fishes of the Stanford expedition to Brazil. Stanford Univ Pub, Univ Ser. 1913; 12:1-77. https://doi.org/10.5962/BHL.TITLE.13885
- **Statista Inc.** Total population of Latin America and Caribbean countries 2022 [Internet]. New York: Statista Inc.; 2022. Available from: https://www.statista.com/statistics/988453/number-inhabitants-latin-america-caribbean-country/
- **Suárez TS.** El valor del agua del Gran Lago Cocibolca para Nicaragua. Rev Tem Nicaragüenses. 2016; 95:39–58. Available from: https://www.scribd.com/doc/297139768/Revista-de-temas-nicaraguenses
- **Sun CC, Hurst JE, Fuller AK.** Citizen science data collection for integrated wildlife population analyses. Front Ecol Evol. 2021; 9:682124. https://doi.org/10.3389/fevo.2021.682124
- **Tanaka T**. Research of freshwater elasmobranchs in Lake Nicaragua. Rep Japan Soc Elasmobr Stud. 1994; 31:26–34. Available from: https://jses-info.translate.goog/mngmnt/wp-content/uploads/report/bansai_report_031.pdf
- **Taniuchi T.** Report on preliminary investigation of freshwater elasmobranchs in Mexico and Central America. Rep Japan Soc Elasmobr Stud. 1992; 29:33–49. Available from: https://jses-info.translate.goog/mngmnt/wp-content/uploads/report/bansai_report_029.pdf
- **Taniuchi T.** Outline of field surveys for freshwater elasmobranchs conducted by a Japanese research team. In: Fowler SL, Reed TM, Dipper FA, editors. Elasmobranch biodiversity, conservation and management. Proceedings of the International Seminar and Workshop, Sabah, Malaysia, July 1997. Gland, Cambridge: IUCN; 2002. p.181-84. Available from: https://portals.iucn.org/library/efiles/documents/ssc-op-025.pdf

- **Tavares R, Sánchez L.** Áreas de cría de tiburones en el Golfo de Venezuela. Ciencia. 2012; 20(2):116-24. Available from: https://www.researchgate.net/publication/262876374_Areas_de_cria_de_tiburones_en_el_Golfo_de_Venezuela
- **Temple AJ, Cochran JE, Pirog A, Dulvy NK, Cortés E, Weigmann S *et al*.** Opportunities to enhance conservation success for sharks. NPJ Ocean Sustain. 2025; 4(1):24. https://doi.org/10.1038/s44183-025-00131-8
- **Testerman CB.** Molecular ecology of globally distributed sharks. [PhD Thesis]. Dania Beach: Nova Southeastern University Oceanographic Center; 2014. Available from: http://nsuworks.nova.edu/occ_stuetd/6
- **Thomerson JE, Thorson TB, Hempel RL.** The bull shark, *Carcharhinus leucas*, from the Mississippi River near Alton, Illinois. Copeia. 1977; 1977(1):166-68. https://doi.org/10.2307/1443522
- **Thorson TB.** Proof from tagging that sharks of Lake Nicaragua are not landlocked. Proc Neb Acad Sci. 1970a; 80:14.
- **Thorson TB.** Chapter 6: A matter of controversy. In: Lineaweaver TH, Backus RH, editors. The natural history of sharks. Philadelphia: J. B. Lippincott Co.; 1970b. p.72–87.
- **Thorson TB.** Movement of the bull shark, *Carcharhinus leucas*, between Caribbean Sea and Lake Nicaragua demonstrated by tagging. Copeia. 1971; 1971(2):336-38. https://doi.org/10.2307/1442846
- **Thorson TB.** The sharks of Lake Nicaragua: visitors from the Caribbean Sea. Hist Nat Pro Nat. 1972a; 4(3):34–36.
- **Thorson TB.** The status of the bull shark, *Carcharhinus leucas*, in the Amazon River. Copeia. 1972b; 3:601–05. https://doi.org/10.2307/1442947
- **Thorson TB.** The status of the Lake Nicaragua shark: an updated appraisal. In: Thorson TB, editor. Investigations of the ichthyofauna of Nicaraguan lakes. Lincoln: University of Nebraska-Lincoln; 1976. p.561-74. Available from: https://digitalcommons.unl.edu/ichthynicar/41
- **Thorson TB.** The impact of commercial exploitation on sawfish and shark populations in Lake Nicaragua. Fisheries. 1982; 7:2–10. https://doi.org/10.1577/1548-8446(1982)007%3C0002:TIOCEO%3E2.0.CO;2
- **Thorson TB, Cowan CM, Watson DE.** Sharks and Sawfish in the Lake Izabal-Rio Dulce System, Guatemala. Copeia. 1966; 1966(3):620–22. https://doi.org/10.2307/1441111
- **Tiktak GP, Butcher D, Lawerence PJ, Norrey J, Bradley L, Shaw K *et al*.** Are concentrations of pollutants in sharks, rays and skates (Elasmobranchii) a cause for concern? A systematic review. Mar Poll Bull. 2020; 160:111701. https://doi.org/10.1016/j.marpolbul.2020.111701
- **Tillett BJ, Meekan MG, Field MC, Thorburn DC, Ovenden JR.** Evidence for reproductive philopatry in the bull shark *Carcharhinus leucas*. J Fish Biol. 2012; 80(6):2140-58. https://doi.org/10.1111/j.1095-8649.2012.03228.x
- **TinHan TC, O'Leary SJ, Portnoy DS, Rooker JR, Gelpi CG, Wells RD.** Natural tags identify nursery origin of a coastal elasmobranch *Carcharhinus leucas*. J Appl Ecol. 2020; 57(7):1222–32. https://doi.org/10.1111/1365-2664.13627
- **Torres-Romero EJ, Pérez Jiménez JC.** Extinction risk of the world's chondrichthyan fishes: a global assessment of the interplay between anthropogenic factors and marine protected areas. Rev Fish Biol Fish. 2024; 34:685–701. https://doi.org/10.1007/s11160-023-09830-2
- **Tuma RE.** An investigation of the feeding habits of the bull shark, *Carcharhinus leucas*, in the Lake Nicaragua-Rio San Juan system. In: Thorson TB, editor. Investigations of the ichthyofauna of Nicaraguan lakes. Lincoln: University of Nebraska-Lincoln; 1976. p.533-38. Available from: https://digitalcommons.unl.edu/ichthynicar/39
- **Turner JA, Starkey M, Dulvy NK, Hawkins F, Mair L, Serckx A *et al*.** Targeting ocean conservation outcomes through threat reduction. NPJ Ocean Sustain. 2024; 3(1):4. https://doi.org/10.1038/s44183-023-00040-8
- **United Nations (UN).** Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Appendices I, II and III valid from 25 May 2024. Nairobi: United Nations Environment Programme; 2024. Available from: https://cites.org/sites/default/files/eng/app/2024/E-Appendices-2024-05-25.pdf

- **Uribe JA.** Distribución, abundancia, estructura y biometría de especies de tiburones capturados en la zona de Campeche, México. [BSc Thesis]. México, D.F.: Universidad Nacional Autónoma de México; 1993. Available from: https://repositorio.unam.mx/contenidos/distribucion-abundancia-estructura-y-biometria-de-especies-de-tiburones-capturados-en-la-sonda-de-campeche-mexico-460856?c=4vRGRy&d=false&q=*:*&i-=1&v=1&t=search_0&as=0
- **Vizotto LD, Taddei VA.** Tubarão da Amazônia. An Acad Bras Ciênc. 1978; 50(3):85.
- **Wakida-Kusunoki AT, Anislado-Tolentino V, Moral-Flores LFD.** First report of synophthalmia and leucism in a bull shark (*Carcharhinus leucas*) embryo from the southeastern Gulf of Mexico. Lat Am J Aquat Res. 2022; 50(5):760–66. http://dx.doi.org/10.3856/vol50-issue5-fulltext-2896
- **Watson DE, Thorson TB.** Helminths from elasmobranchs in Central American fresh waters. In: Thorson TB, editor. Investigations of the ichthyofauna of Nicaraguan lakes. Lincoln: University of Nebraska-Lincoln; 1976. p.629-40. Available from: https://digitalcommons.unl.edu/ichthynicar/52
- **Werder U, Alhanati CE.** Informe sobre um tubarão (*Carcharhinus leucas*), capturado no Amazonas com alguns detalhes de sua morfologia externa. Acta Amazon. 1981; 11(1):193-96. https://doi.org/10.1590/1809-43921981111193
- **Werry JM, Lee SY, Otway NM, Hu Y, Sumpton W.** A multi-faceted approach for quantifying the estuarine–nearshore transition in the life cycle of the bull shark, *Carcharhinus leucas*. Mar Freshw Res. 2011; 62(12):1421–31. https://doi.org/10.1071/MF11136
- **Williams G.** Adaptation and Natural Selection. Princeton: Princeton University Press; 1966.
- **Williams L, Lucrezi S, Cowley P, Gennari E.** Stakeholders' perceptions of the conservation and management of elasmobranchs in South Africa. Mar Policy. 2023; 157:105847. https://doi.org/10.1016/j.marpol.2023.105847
- **Worm B, Orofino S, Burns ES, D'Costa NG, Feitosa LM, Palomares MLD *et al*.** Global shark fishing mortality still rising despite widespread regulatory change. Science. 2024; 383(6679):225–30. https://doi.org/10.1126/science.adf8984
- **Wosnick N, Martins APB, Leite RD, Giareta EP, Faria VV, Charvet P.** Chapter: Brazil. In: Jabado RW, Morata AZA, Bennett RH, Finucci B, Ellis JR, Fowler SL *et al*, editors. The global status of sharks, rays, and chimaeras. Gland, Switzerland: IUCN; 2024. p.441–456. https://doi.org/10.59216/ssg.gsrsrc.2024
- **Wosnick N, Palmeira ARO, Nunes JL.** Pinocchioland: the role of the Brazilian Amazonian coast in elasmobranch conservation. Science. 2019; 334(6187):1246752. Available from: https://www.science.org/doi/10.1126/science.1246752
- **Yáñez-Arancibia A, Linares FA, Day Jr JW.** Fish community structure and function in Terminos Lagoon, a tropical estuary in the southern Gulf of Mexico. In: Kennedy VS, editor. Estuarine Perspectives. London: Academic Press; 1980. p.465–82. https://doi.org/10.1016/B978-0-12-404060-1.50044-7
- **Yegres H, Alió JJ, Marcano LA, Marcano JS.** Análisis preliminar de la pesquería y biología de tiburones en Venezuela. Col Vol Sci Pap ICCAT. 1996; 45(3):309–15. Available from: https://www.iccat.int/Documents/CVSP/CV045_1996/colvol45.html#
- **Zarate P, Hearn A.** Estado de conservación de los tiburones de Nicaragua, Costa Rica, Panama, Colombia y Ecuador. Quito: Charles Darwin Foundation/IUCN; 2008. Available from: https://media.migramar.org/uploads/archive/731.pdf

AUTHORS' CONTRIBUTION

Peter Gausmann: Conceptualization, Data curation, Investigation, Methodology, Supervision, Writing-original draft, Writing-review and editing.
Philip Matich: Methodology, Validation, Visualization, Writing-original draft, Writing-review and editing.
Nadia Sandoval Laurrabaquio-Alvarado: Investigation, Writing-original draft, Writing-review and editing.

ETHICAL STATEMENT

Not applicable.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are included in the supplementary material of this article.

COMPETING INTERESTS

The authors declare no competing interests.

FUNDING

The authors received no financial support for the research, authorship, and publication of this article.

HOW TO CITE THIS ARTICLE

- **Gausmann P, Matich P, Laurrabaquio-Alvarado NS.** Research goals of special concern for *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae) in Latin America – biological, distributional, and conservation priorities. Neotrop Ichthyol. 2025; 23(3):e250034. https://doi.org/10.1590/1982-0224-2025-0034

Neotropical Ichthyology

OPEN ACCESS

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Distributed under
Creative Commons CC-BY 4.0

© 2025 The Authors.
Diversity and Distributions Published by SBI

SBI
Official Journal of the
Sociedade Brasileira de Ictiologia

TABLE S1 | Country-based overview on identified, requested, and responding scientists (absolute numbers; countries ordered alphabetical).

Country / oversea territory	Number of identified and requested scientists	Number of responding scientists
Argentina	2	1
Belize	1	0
Brazil	43	12
Colombia	6	2
Costa Rica	5	3
Cuba	4	1
Dominican Republic	0	0
El Salvador	0	0
Ecuador	5	0
French Guyana	1	0
Guatemala	4	2
Guyana	1	0
Haiti	0	0
Honduras	2	1
Jamaica	0	0
Mexico	19	8
Nicaragua	1	0
Panama	3	2
Peru	3	2
Puerto Rico	3	0
Suriname	2	2
Uruguay	2	0
Venezuela	3	1
∑ **23**	∑ **110**	∑ **37**

Neotropical Ichthyology

OPEN ACCESS

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Distributed under
Creative Commons CC-BY 4.0

© 2025 The Authors.
Diversity and Distributions Published by SBI

Official Journal of the
Sociedade Brasileira de Ictiologia

HOW TO CITE THIS ARTICLE

- **Gausmann P, Matich P, Laurrabaquio-Alvarado NS.** Research goals of special concern for *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae) in Latin America – biological, distributional, and conservation priorities. Neotrop Ichthyol. 2025; 23(3):e250034. https://doi.org/10.1590/1982-0224-2025-0034

TABLE S2 | Overview of recent records of *Carcharhinus leucas* from fresh and brackish water habitats at five locations of special concern in Latin America deriving from media reports (only records considered that have not yet been previously published in scientific literature).

Toponym	Locality	Year of report	Type of observation	Number of observed specimens	Age classand sex	Type of record	Type of source / reference	Comments
Terminos Lagoon	Aguada Island	2022	Accidentally catch by artisanal fishers	1	Subadult	Media report	Online newspaper (Graniel Herrera, 2022)	Reported capture of *C. leucas* at Puente de la Unidad / Boca de Puerto Real
	Ciudad del Carmen	2022	Accidentally catch by artisanal fishers	1	Adult	Media report	Online newspaper (Castro, 2022)	Reference provided a picture of a gravid female
Lake Izabal-Dulce River system	Castillo de San Felipe de Lara	2021	Citizen observation	1	Juvenile	Media report	News report (Canal 3 Guatemala, 2021)	Video footage produced by citizens displayed in the national news
Lake Nicaragua-San Juan River system	San Ramon, Ometepe Island (Biological Field Station)	2000	Accidentally catch by artisanal fishers using gill net	2	Subadult	Social media report	Social media (Organización Nicaragüense Ambiental, 2014)	Photographic evidence of an occurrence of two specimens displayed together
	San Juan River (not further specified)	2020	Citizen observation	1	Subadult	Media report	Online newspaper (Información Puntual, 2020)	Report on one dead specimen floating at the water surface
Lake Maracaibo	Punta de Palmas (near the village Miranda)	2022	Accidentally catch by artisanal fishers using gill net	1	Adult female	Media report	Online newspaper (NotiActual, 2022)	The reference gives information on five additional bull shark specimens that were also caught in 2022 near Punta de Palmas
	Punta de Palmas (near the village Miranda)	2022	Accidentally catch by artisanal fishers	1	Adult	Media report	Online newspaper (Foco Informativo, 2022)	At least five bull sharks were caught in 2022, all in the Punta de Palma sector on the coast at Miranda
Amazon River system	Limoeiro do Ajuru (at the confluence of the Limoeiro and Tocantins Rivers)	2022	Accidentally catch by artisanal fishers	1	Juvenile	Media report	Online newspaper (Pires, 2022)	Media report of a juvenile specimen of ~120 cm TL. This reported specimen occurred at ~220 km distance to the sea

REFERENCES

- **Canal 3 Guatemala, editors.** Imágenes de un tiburón en las aguas del Lago de un río en Izabal [Internet]. Guatemala City: Grupo Chapín TV; 2021. Available from: https://www.youtube.com/watch?v=rWSpR33D_2A
- **Castro G.** Tiburones rodean la isla de Ciudad del Carmen, Campeche [Internet]. Mérida, Yucatán, Mexico: Publicidad Poresto; 2022. Available from: https://www.poresto.net/campeche/2022/12/2/tiburones-rodean-la-isla-de-ciudad-del-carmen-campeche-361901.html
- **Foco Informativo, editors.** Capturan un tiburón en el Lago de Maracaibo [Internet]. Caracas: Foco Informativo; 2022. Available from: https://focoinformativo.com/capturan-un-tiburon-en-el-lago-de-maracaibo
- **Graniel Herrera G.** Presencia de tiburones en Isla Aguada ahuyenta al turismo [Internet]. Mérida, Yucatán, Mexico: La Journada Maya; 2022. Available from: https://www.lajornadamaya.mx/campeche/206333/presencia-de-tiburones-en-isla-aguada-ahuyenta-al-turismo

- **Información Puntual, editors.** Depredador del mar regresa al Lago de Nicaragua [Internet]. Managua: Información Puntual; 2020. Available from: https://ipnicaragua.com/depredador-del-mar-regresa-al-lago-de-nicaragua
- **NotiActual, editors.** Pescan Tiburones en el Lago de Maracaibo [Internet]. Caracas: NotiActual; 2022. Available from: https://www.notiactual.com/insolito-pescan-tiburones-en-el-lago-de-maracaibo
- **Organización Nicaragüense Ambiental.** Aun hay tiburones de agua dulce en nuestro Gran Lago de Nicaragua [Internet]. Managua: Organización Nicaragüense Ambiental; 2014.
- **Pires G.** Tubarão-touro é encontrado por pescadores em Limoeiro do Ajuru [Internet]. São Paulo: O Liberal; 2022. Available from: https://www.oliberal.com/para/pescadores-de-limoeiro-do-ajuru-no-nordeste-paraense-encontram-tubarao-touro-1.572312

Neotropical Ichthyology

OPEN ACCESS

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Distributed under
Creative Commons CC-BY 4.0

© 2025 The Authors.
Diversity and Distributions Published by SBI

Official Journal of the
Sociedade Brasileira de Ictiologia

SBI

HOW TO CITE THIS ARTICLE

- **Gausmann P, Matich P, Laurrabaquio-Alvarado NS.** Research goals of special concern for *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae) in Latin America – biological, distributional, and conservation priorities. Neotrop Ichthyol. 2025; 23(3):e250034. https://doi.org/10.1590/1982-0224-2025-0034

TABLE S3 | Overview of voucher specimens of *Carcharhinus leucas* collected at the investigation sites as identified by the authors that are housed in ichthyological collections. Data obtained from Garrick (1982), Howe, Springer (1993), Soto, Mincarone (2004), and National Science Foundation (2016). Numbers with asterisk = locations that were also mentioned by the interviewed Latin American scientists.

Nº	Toponym	Catalog number (incl. available information of specimens)
1*	Gulf of California	CAS SU 53658 TCWC 15531.01
2	Terminos Lagoon	MCZ 39638 (62 cm TL) MCZ 39639 (61 cm TL) MCZ 39640 (60 cm TL)
3	Lake Izabal-Dulce River system	USNM 134326 (69.2 cm TL, ♀; 91.5 cm TL, ♀) USNM 134327 USNM 134328 USNM 146541 (94 cm TL, ♂) USNM 146542 (127 cm TL, ♀)
4	Lake Nicaragua-San Juan River system	MCZ 35896 (146 cm TL, ♂) TU 24511 UCLA 62-56 (three sets of jaws) UCR 1082-001 UCR 1089-001 USNM 120371 (*ca.* 133 cm TL, ♂) USNM 120372 (*ca.* 162 cm, TL, ♂) USNM 120373 (*ca.* 180 cm TL, ♂) USNM 16887 (193 cm TL, skin, skull, jaws, ♂; Holotype of *Eulamia nicaraguensis* Gill, 1877) USNM 39913
5*	Panama Canal and Lake Gatun	USNM 127134 (*ca.* 110 cm TL, skin, ♀)
6*	Lake Maracaibo	No material collected
7*	Amazon River system	CMNFI 1974-0095.1 MOVI 10179 (*ca.* 230 cm TL, photographs, ♂) NMW 61-418 (66.5 cm TL, embryo, ♂)

Neotropical Ichthyology

OPEN ACCESS

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Distributed under
Creative Commons CC-BY 4.0

© 2025 The Authors.
Diversity and Distributions Published by SBI

Official Journal of the
Sociedade Brasileira de Ictiologia

HOW TO CITE THIS ARTICLE

- **Gausmann P, Matich P, Laurrabaquio-Alvarado NS.** Research goals of special concern for *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae) in Latin America – biological, distributional, and conservation priorities. Neotrop Ichthyol. 2025; 23(3):e250034. https://doi.org/10.1590/1982-0224-2025-0034

TABLE S4 | Research goals targeting *Carcharhinus leucas* summarized for each region/state/department of the respective Latin American countries with responding scientists, sorted by ocean basins.

Atlantic Ocean (incl. Gulf of Mexico, Caribbean Sea)		
Country	**Region/State/Department**	**Research goal / topic**
Mexico	Tamaulipas	Identification of nurseries and other conservation areas, occurrence in artisanal fisheries, genetic population structure
	Tabasco	Life history and biology, identification of nurseries and other conservation areas, occurrence in artisanal fisheries, genetic population structure
	Campeche	Life history and biology, identification of nurseries and other conservation areas, occurrence in artisanal fisheries, genetic population structure
	Quintana Roo	Life history and biology, non-fisheries human impacts (pollution), occurrence in artisanal fisheries, genetic population structure
Cuba	Gulf of Mexico (Pinar del Rio, Artemisa, La Habana, Mayabeque)	Non-nursery habitat use and distribution, fisheries impact, occurrence in artisanal fisheries
Guatemala	Izabal	Non-nursery habitat use and distribution, life history and biology, identification of nurseries and other conservation areas, genetic population structure
Honduras	Honduran Caribbean (Cortés, Atlántida, Colón, Gracias a Dios)	Life history and biology, fisheries impact, occurrence in artisanal fisheries
Colombia	Colombian Caribbean (La Guajira, Magdalena, Atlántico, Bolívar, Sucre, Córdoba, Antioquia, Chocó)	Fisheries impacts, identification of nurseries and other conservation areas
Venezuela	Gulf of Venezuela & Lake Maracaibo (inland waters)	Non-nursery habitat use and distribution, non-fisheries human impacts (habitat degradation, pollution),
	Northeastern Venezuela (Isla de Margarita)	Non-nursery habitat use and distribution
Suriname	Atlantic Ocean (Nickerie, Coronie, Saramacca, Wanica, Paramaribo, Commewijne, Marowijne)	Fisheries impact, occurrence in artisanal fisheries
	Suriname River (inland waters)	Non-nursery habitat use and distribution,
Brazil	Amazonas (inland waters)	Life history and biology, identification of nurseries and other conservation areas
	Pará (Brazilian Amazon coast, Amazon River mouth & inland waters)	Non-nursery habitat use and distribution, life history and biology, fisheries impacts, identification of nurseries and other conservation areas, non-fisheries human impacts (pollution), occurrence in artisanal fisheries, non-human impacts (climate change)
	Maranhão (Brazilian Amazon coast)	Non-nursery habitat use and distribution, life history and biology, fisheries impact, identification of nurseries and other conservation areas, non-fisheries human impacts (pollution), occurrence in artisanal fisheries, non-human impacts (climate change)
	Pernambuco	Non-nursery habitat use and distribution, life history and biology, identification of nurseries and other conservation areas, non-fisheries human impacts (pollution), occurrence in artisanal fisheries, ecological role, shark bites
	Alagoas	Identification of nurseries and other conservation areas
	Espírito Santo	Non-nursery habitat use and distribution, life history and biology, identification of nurseries and other conservation areas
	Paraná	Non-nursery habitat use and distribution, life history and biology, fisheries impacts, non-fisheries human impacts (pollution), occurrence in artisanal fisheries, , non-human impacts (climate change)
	Rio Grande do Sul	Non-fisheries human impacts (habitat degradation), non-human impacts (climate change)
Argentina	Rio de la Plata region	Non-nursery habitat use and distribution

TABLE S4 | (Continued)

Pacific Ocean (incl. Gulf of California)		
Country	**Region/State/Department**	**Research goal / topic**
Mexico	Baja California Sur	Life history and biology, fisheries impact, identification of nurseries and other conservation areas, non-fisheries human impacts (pollution)
	Sinaloa	Identification of nurseries and other conservation areas, non-fisheries human impacts (habitat degradation)
	Nayarit	Identification of nurseries and other conservation areas, non-fisheries human impacts (habitat degradation)
Guatemala	Guatemalan Pacific (San Marcos, Retalhuleu, Suchitepéquez, El Progreso, Santa Rosa, Jutiapa)	Identification of nurseries and other conservation areas
Costa Rica	Nicoya Peninsula / Gulf of Nicoya	Non-nursery habitat use and distribution, fisheries impacts, identification of nurseries and other conservation areas, non-fisheries human impacts (habitat degradation, pollution)
Panama	Panamanian Pacific	Non-nursery habitat use and distribution, life history and biology, fisheries impacts, occurrence in artisanal fisheries
	Panama Canal (inland waters)	Identification of nurseries and other conservation areas
Colombia	Colombian Pacific (Chocó, Valle del Cauca, Cauca, Nariño)	Life history and biology, fisheries impacts, identification of nurseries and other conservation areas, ecological role
Peru	Tumbes	Non-nursery habitat use and distribution, fisheries impacts, identification of nurseries and other conservation areas, non-fisheries human impacts (habitat degradation, pollution), genetic population structure, non-human impacts (extreme climate events)

Neotropical Ichthyology

OPEN ACCESS

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

Distributed under
Creative Commons CC-BY 4.0

© 2025 The Authors.
Diversity and Distributions Published by SBI

Official Journal of the
Sociedade Brasileira de Ictiologia

SBI

HOW TO CITE THIS ARTICLE

- **Gausmann P, Matich P, Laurrabaquio-Alvarado NS.** Research goals of special concern for *Carcharhinus leucas* (Carcharhiniformes: Carcharhinidae) in Latin America – biological, distributional, and conservation priorities. Neotrop Ichthyol. 2025; 23(3):e250034. https://doi.org/10.1590/1982-0224-2025-0034